MCG 1100 - Introduction to Mechanical Engineering

Dissection Lab 8 - Joining Methods

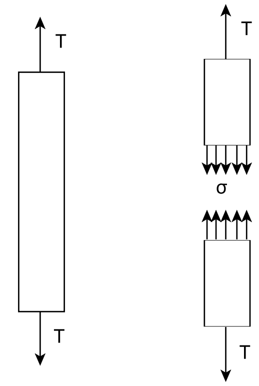
(prepared by M. Munro, revised by W. Hallett)

In this lab we will examine several different methods of joining two metal strips together. We will test sample joints to failure in tension and draw conclusions about the failure mode in each case.

1. Failure of Structural Elements

There are several different ways in which materials and mechanical components can fail. In complex structures and parts more than one mode of failure may be possible, and the designer must ensure that all possible modes are covered to ensure a safe design.

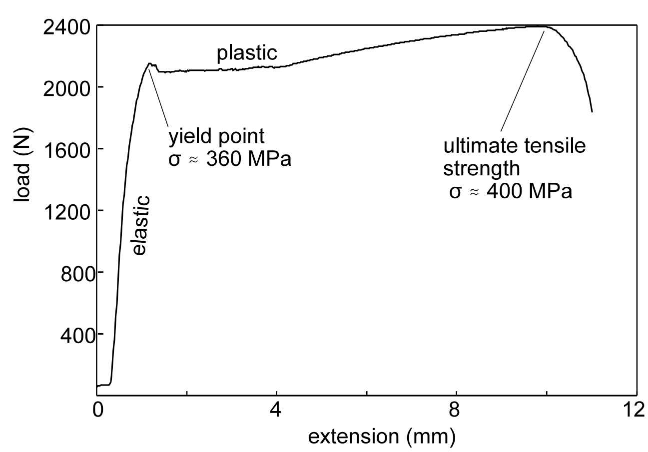
1.1 Tension Failure



Failure in **tension** is breaking normal to the applied load. The strength of the material is characterized by the stress σ, which is defined as the applied tensile force divided by the cross-sectional area A of the part:

$$\sigma = T / A$$

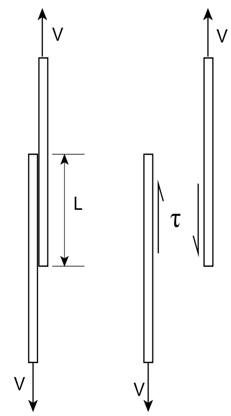
This is usually given in units of MPa (MN / m^2 = N / mm^2) or GPa. Failure will occur when σ exceeds the characteristic value for a given material as determined by testing; metals typically fail at stresses ranging from 200 (copper) - 1200 MPa (high-strength steel), with 400MPa being a typical value for an ordinary steel.



"Failure" here may be defined as actual breaking of the specimen (the **ultimate tensile stress**). However, most metals begin to yield and deform plastically before they break. The figure shows a typical load versus extension curve for the soft steel strip used in this lab. The material initially deforms elastically (*i.e.* if the load were removed it would return to its original length), but at a point called the **elastic limit** or **yield point** it begins to deform plastically. This particular sample undergoes a great deal of plastic deformation before it breaks, and as it deforms it work hardens, so the load increases until the ultimate tensile strength is reached. For most design purposes the **yield stress** - the point at which plastic deformation begins - is more important than the ultimate tensile stress. Area A may be taken as the original cross-section of the piece (before loading), but the true stress at failure is calculated from the cross-section of the failed section, which is often smaller than the original value because of deformation during loading.

The tensile test - the one that we will subject our joints to - is the simplest and most fundamental way of evaluating a material's strength and behaviour.

1.2 Shear Failure

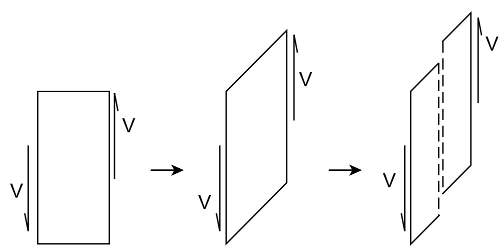


The second common mode of failure is **shear** - sliding of one piece past another. The stress in this case is the **shear stress** τ, defined as the shear force V divided by the area sheared A:

$$\tau = V / A$$

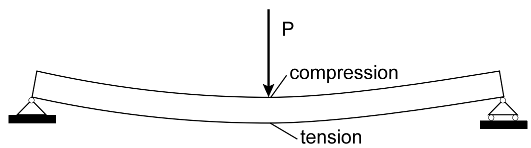
where $A = w\,L$ and w is the width of the material. The units are the same as for tensile stress.

Loading of a material under shear causes the material to deform as in the figure, and failure occurs along a plane parallel to the load. This is the sort of failure that occurs when you cut a material with scissors or shears, hence the name. As with tensile failure, the material may yield in plastic deformation before actually breaking. Again, materials have characteristic values of shear strength, which in most cases are different from their tensile strength.

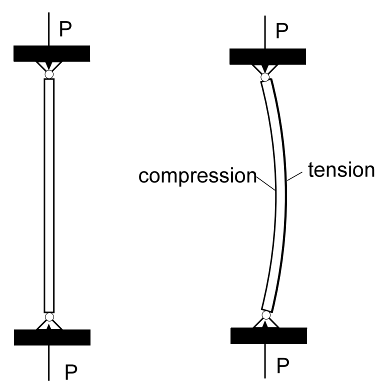


1.3 Other Failure Modes

Bending of a long beam stretches one side and compresses the other. Failure is usually in tension on the side being stretched.



Compression failures are more complex. Long pieces under compression will fail by buckling - sideways bowing of the member. Failure is again in bending, and therefore due to tension on the side which stretches. Short pieces fail in a complex manner involving shear at an angle to the load.



There are two other failure mechanisms which operate over long time periods:

- **fatigue** is failure under cyclic loading, such as the repeated bending of a metal strip back and forth.

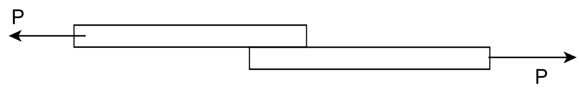
- **creep** is gradual plastic deformation with time under a constant load.

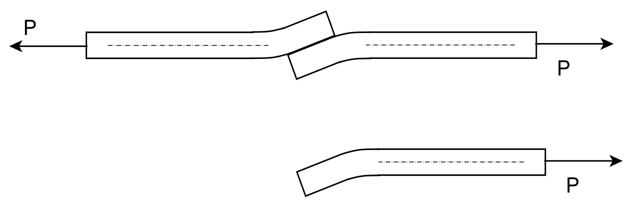
2. Shear Joints

Why shear joints?

- because shear allows the load to be distributed over a large area

2.1 Single lap joints

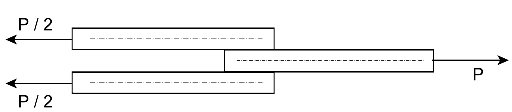


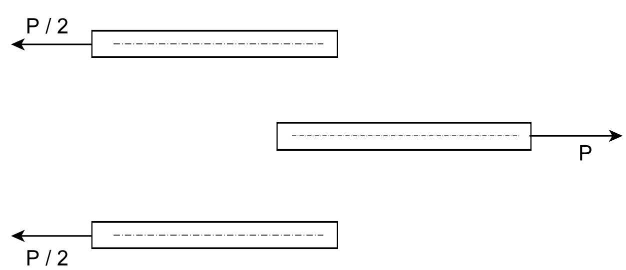


- couple created at joint deforms joint

- joint put partially in tension - can cause joint to "peel" apart

2.2 Double lap joints

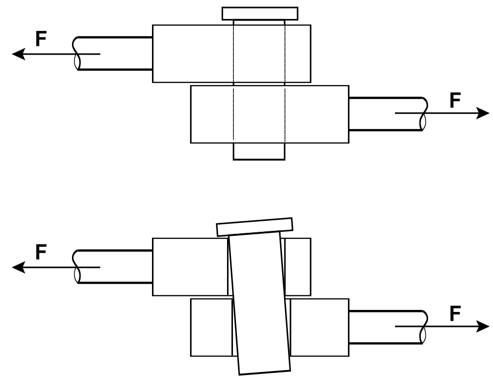




- couples at joint cancel out, joint is in pure shear

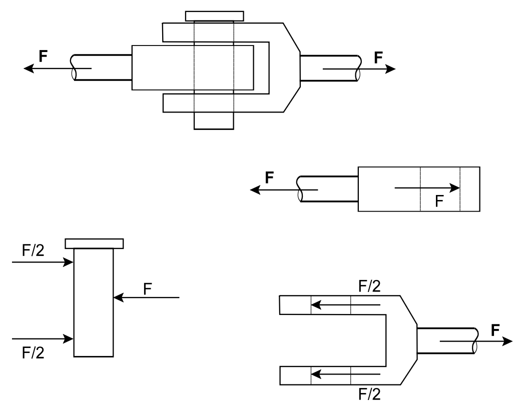
- twice the shear area, therefore half the shear stress of the single-lap joint

2.3 Joints with pin, screw or rivet



Pinned single lap joint

The sketch at the right shows in an exaggerated fashion what happens when a pinned single lap joint is loaded: the pin is pulled to an angled position, and only contacts the holes at two points. This applies moments both to the pin and to the joints, resulting in twisting and distortion similar to that shown above. For this reason, a pinned single lap joint is not good design practice except for light loads.



Double-lap pinned joint (clevis joint)

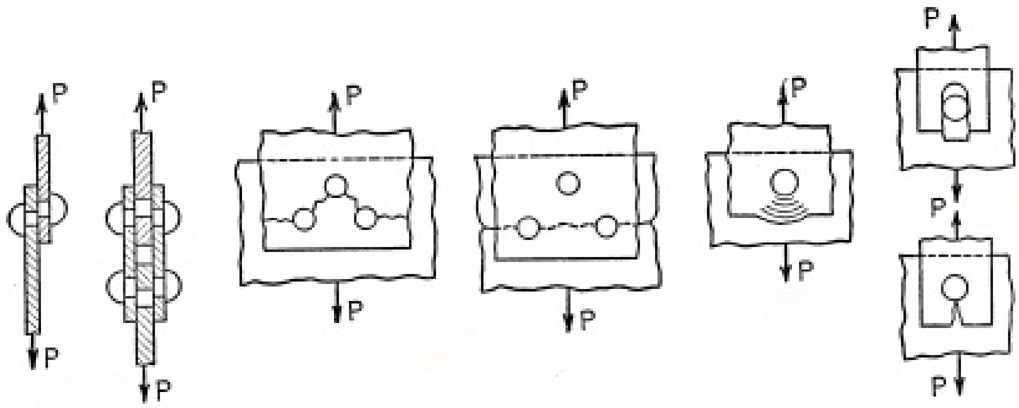
A double-lap pinned joint (also called a clevis joint), on the other hand, does not have this problem. The free-body diagrams of the parts show that the pin in this case is in almost pure shear. There is a bending moment produced in the pin because **F** and **F**/2 are applied at different locations, but it will be very small because the distance between **F** and **F**/2 is small.

3. Assembly Methods

(a) Mechanical

- screws
    - if loose - *all load carried by screw*
    - if tight - *some load carried by friction*
- rivets
- pins

Bolted, pinned or rivetted joints may fail in a number of different ways:



from Seely, *Resistance of Materials,* Wiley, 1935.

(b) Welding

- metal pieces partially melt and solidify into one
- heating may cause local change in material properties (hardness, strength)
- can be used for joints in tension, compression or shear

(c) Adhesives

- requirements: clean, smooth, dry surface, thin layer of adhesive
    - surface should be roughened in direction normal to load

- work best when *joint is in shear*

References: *Marks' Standard Handbook*

- pp. 5.1 – 5.14 (strength, failure of materials)
- pp. 13-29 – 13-35 (welding)
- pp. 6-133 – 6-139 (adhesives)