Riveted Joints

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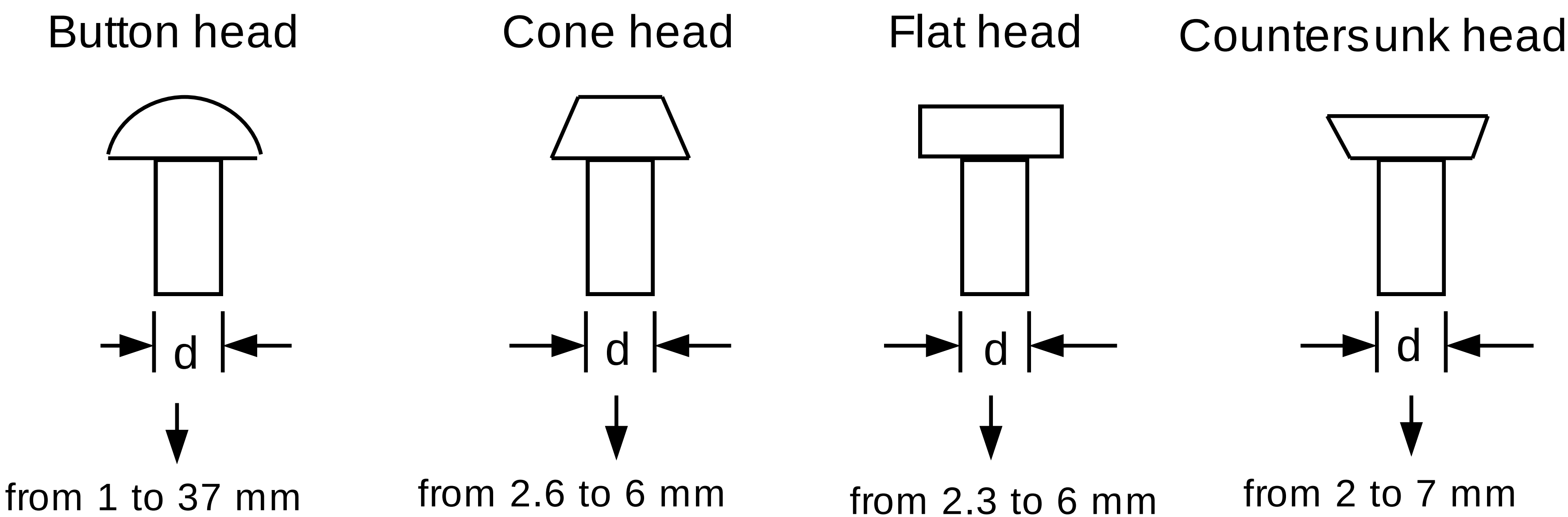
What is a Rivet?

- A rivet is a short bar with a head already formed at one end.
- It is used to make permanent joints between two plates. Rivet is inserted into the holes of plates (which are to be joined) and then its protruding part is upset by a hammer.
- Riveted Joints are classified as permanent joints (e.g. Unlike the joints made by nut and bolts) and disassembling of parts is not possible without destroying the rivets

- Typical types of rivets (ASME boiler Code)



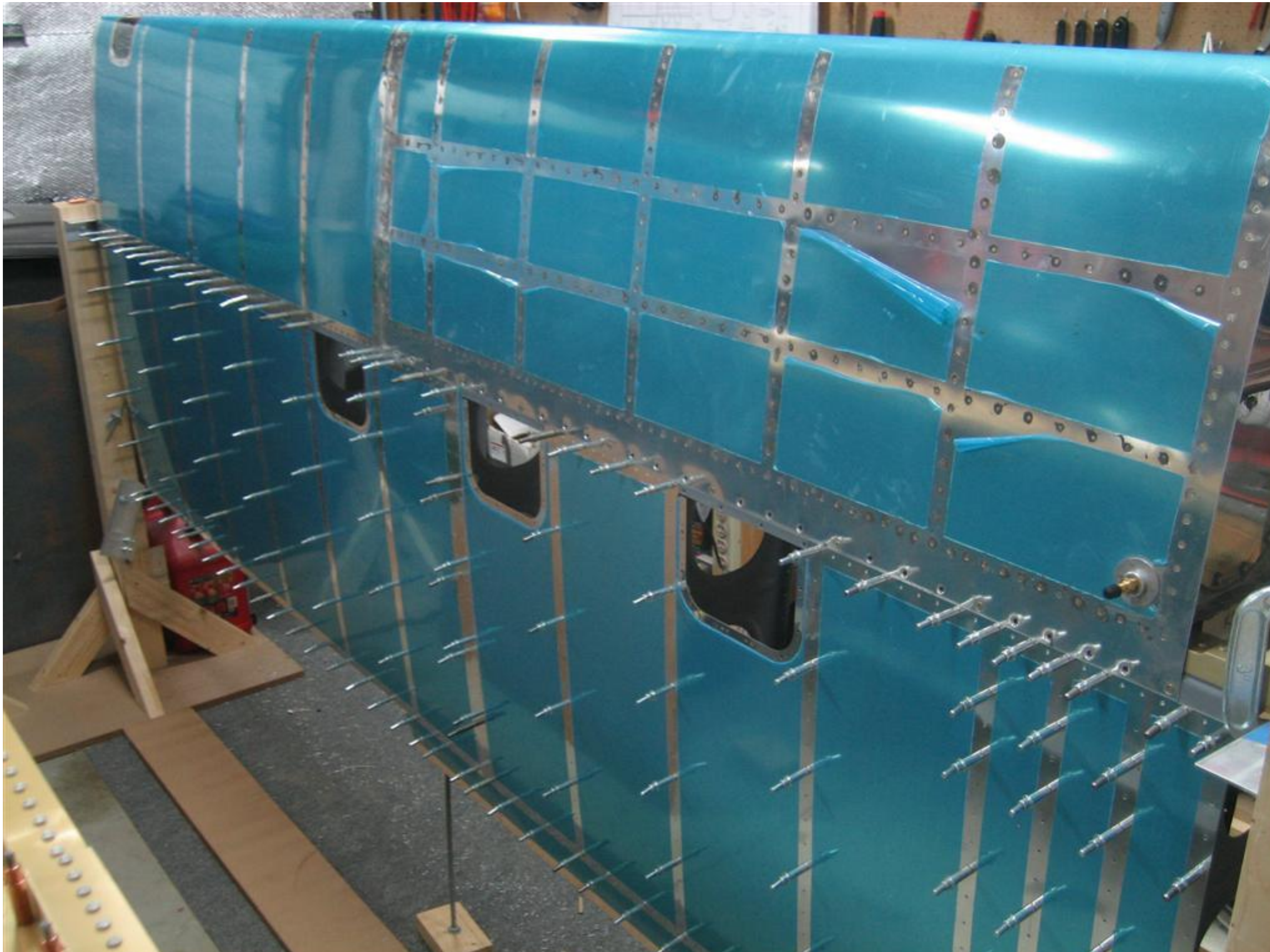
- Rivet is used where we have to avoid after thermal effects, as in case of welding
- Used for metals which have poor weldability
- Used for heterogeneous materials like asbestos friction lining and steel
- As welded joints have poor vibration damping capabilities so where required rivets are used in place of it
- Used for aircraft structure where Aluminium is used
- Generally used for;
  - Steel structures
  - Bridges
  - Cranes
  - Railroad cars
  - Boilers
  - Water Tanks
  - Ships

Fire building

Iron bridge

Railway bridge

Pressure vessel



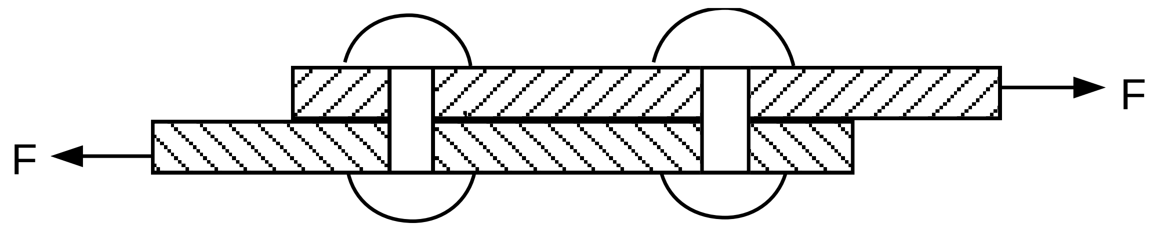
- Material of the rivets;
  - Soft steel
  - Brass
  - Aliminium alloys (ALMG, ALCuMg)
  - Titanium

- Because of galvanic action (occurs when two different material joint together) and thermal expansion, same materials are used for the plates and the rivets.

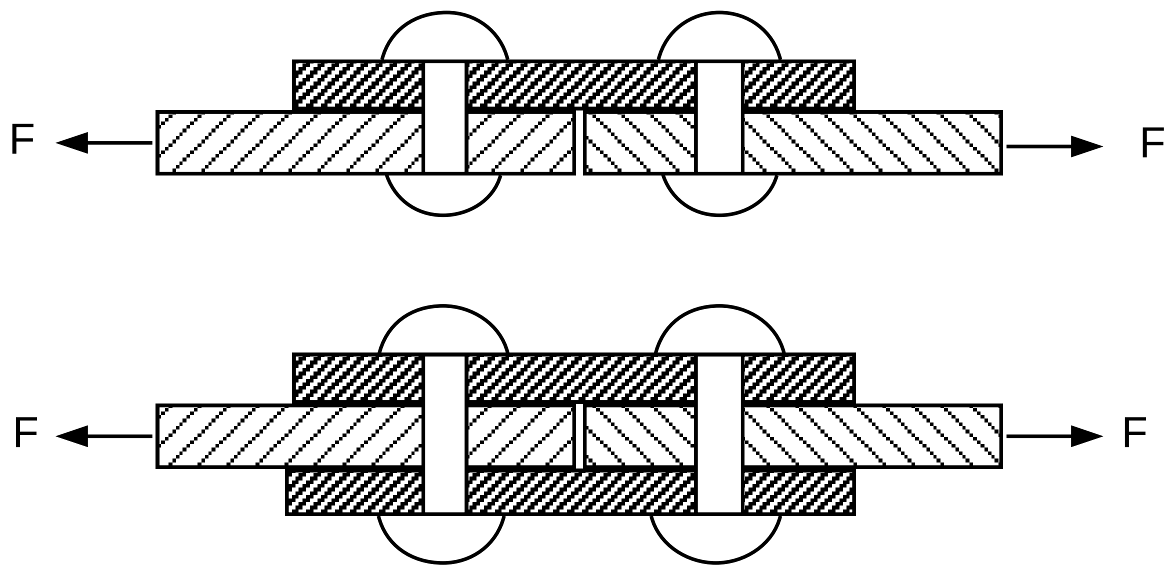
- Advantages of Riveted Joints
  - It is more reliable
  - It can also be used for non ferrous metals
  - Parts assembled by Riveted joint do not have any thermal after effects
  - Its quality inspection is easy and cheap
  - When parts are dismantled riveted parts have less damage compared to welded parts

- Disadvantages of Riveted joints
  - Due to holes plates become weak
  - Labor cost is more
  - Overall cost of riveted joints is more
  - They have more weight than welded joints
  - Riveting process creates more noise
  - Stress concentration near holes

- Riveted joints are generally classified into two main groups:



Lap joint

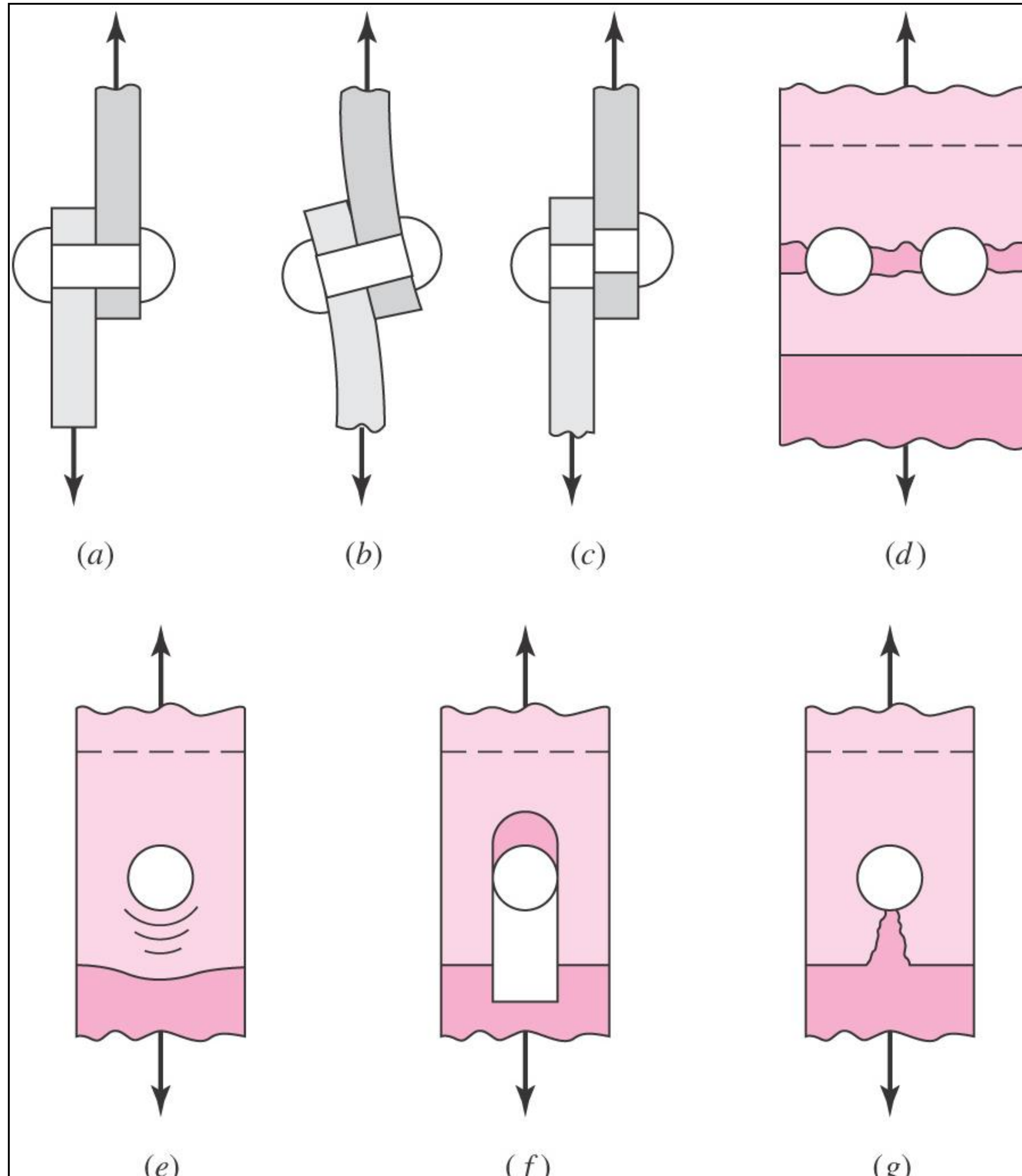


Butt joints

- Rivets must be spaced neither too close nor too far apart as in the case of bolted joints.
- The distance between rivets in a row in riveted joint pattern is known as the Pitch.
- The distance between rows is known as the Transverse Pitch.
- As a general guideline for steel or aluminum plates, the minimum rivet spacing, center to center (pitch), is usually taken as three rivet diameters. A somewhat closer spacing is used in boilers.
- Rivets should not be spaced too far apart or buckling of the plates will take place. The maximum spacing is usually taken as 16 times the thickness of the outside plate.

Failure Types

- Riveted joints must be checked for the following types of failures
  a) Joint loaded in shear
  b) Bending rivet
  c) Shear of rivet
  d) Tensile failure of members
  e) Bearing stress on rivet or members
  f) Shear tear-out
  g) Tensile tear-out



- In examing of the above modes of failure, we assume that;
  a) the rivets completely filled the connecting holes,
  b) the rivet shear stress is distributed uniformly over the cross sectional rivet area,
  c) the tensile load carried by the plate is also distributed equally across the plate material,
  d) the effect of friction between plates riveted in carrying the load is ignored.
  e) In the calculation of shear stresses, cross sectional area of all rivets must be considered ($\tau = F/A$ and $A = N\pi d^2/4$).

- For all riveted joints, these two terms must be clarrified;
    1. Strength of the Joint, is described as the largest load we can safely apply to the joint.
    2. Efficiency of the Joint.

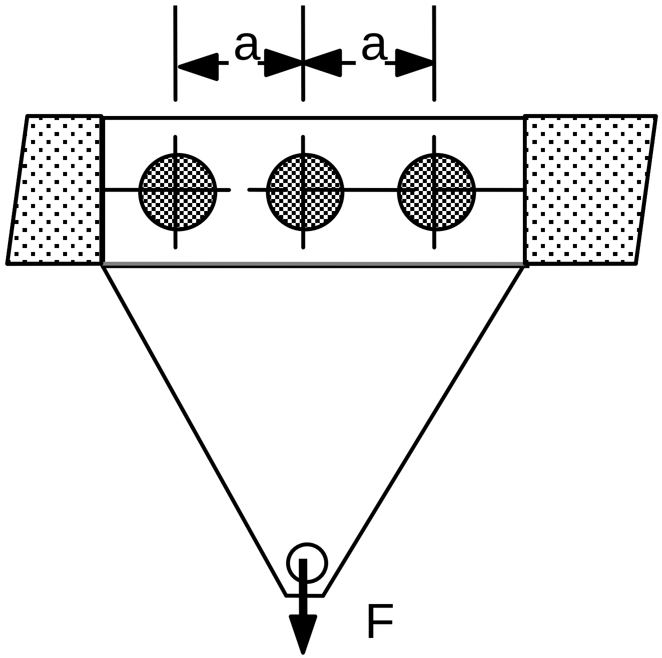
It is described as the ratio of the strength of the joint to the strength of the plate.

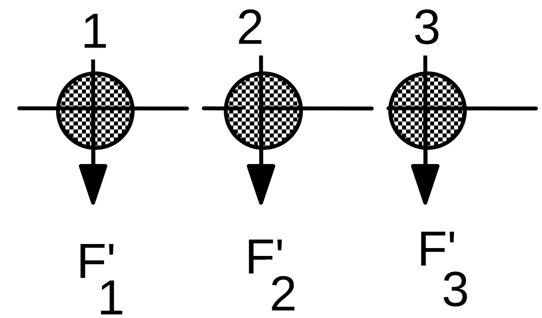
The strength of the plate lid is equal to the area of the plate times the allowable tensile stress of the plate material.

Fplate=(w*t)*Plate strength

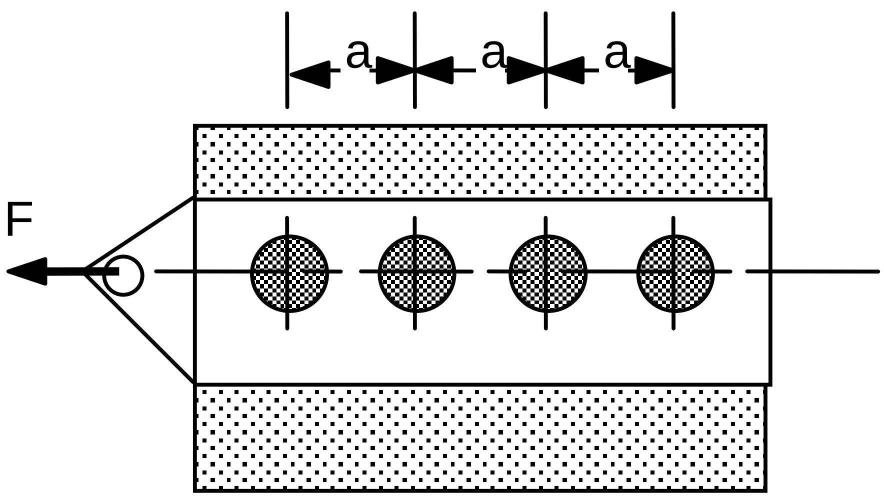
Procedure in the solution of the rivet problems

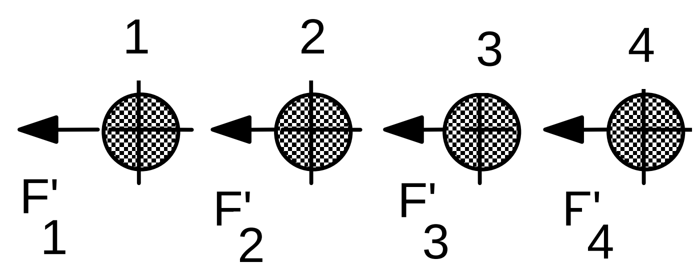
1. Examine the type of joint (lap joint or butt joint)
2. Determine the location of the centroid of the rivet group(if there is more than one rivet in the joint)
3. Check the position of external load with respect to centroid. If the load is passing through the centroid, we will have primary shear forces only. If there is an eccentricity between the line of action of the force and the centroid, this indicates the existance of secondary shear forces due to twisting moment. Twisting moment is external force times vertical distance from the line of action to the centroid)
4. Combine the primary and secondary shear forces to obtain total shear load on each rivet
5. Select the worstly loaded rivet(critical rivet) and base calculations on this rivet.
6. You may use any failure criteria (maximum shear stress theory or distortion energy theory)



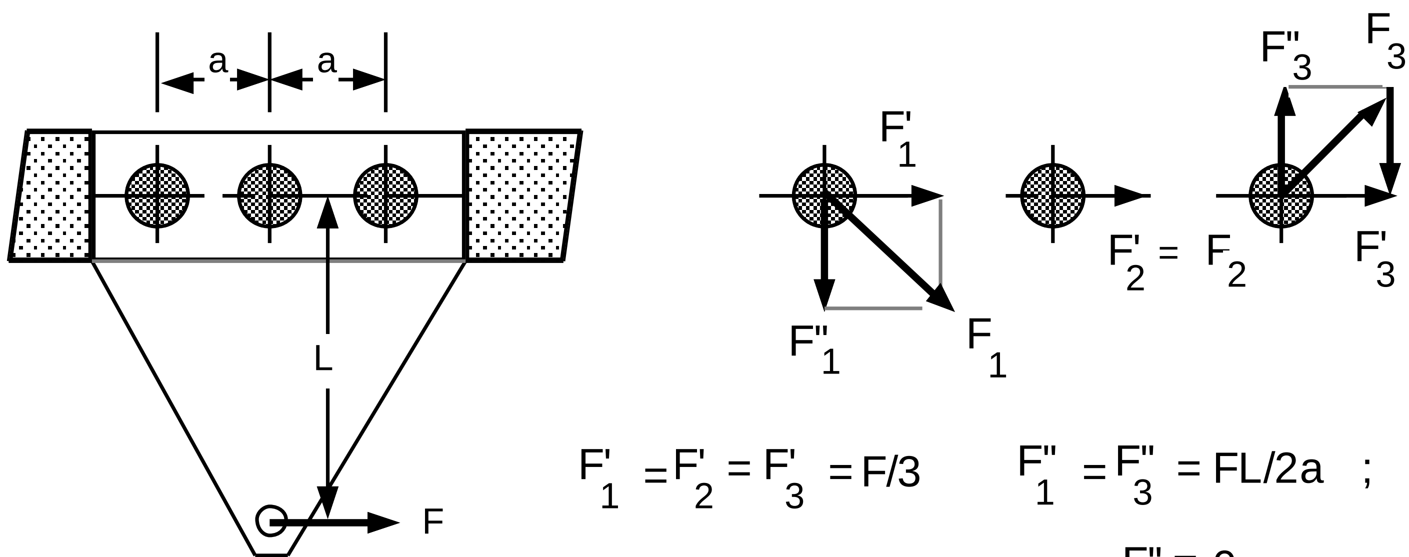


$$F'_1 = F'_2 = F'_3 = F/3$$



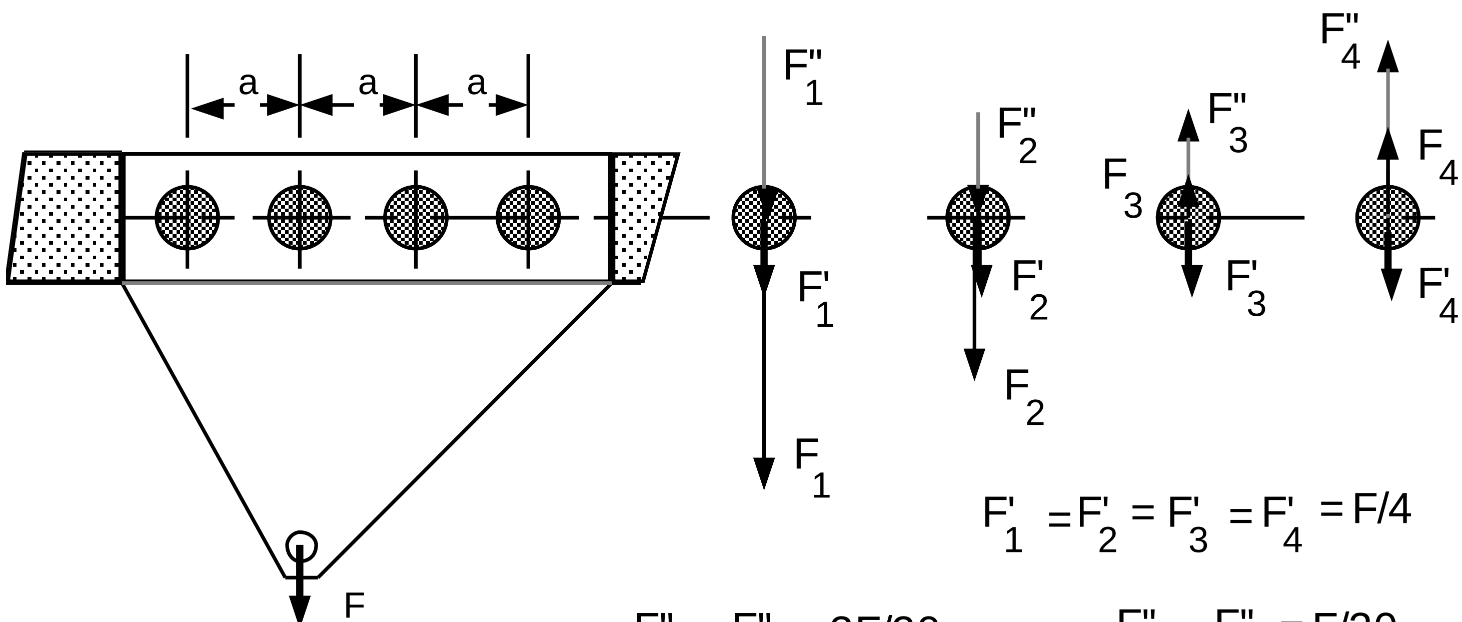


$$F'_1 = F'_2 = F'_3 = F'_4 = F/4$$



$$F'_1 = F'_2 = F'_3 = F/3 \qquad F''_1 = F''_3 = FL/2a \quad ;$$

$$F''_2 = 0$$



$$F'_1 = F'_2 = F'_3 = F'_4 = F/4$$

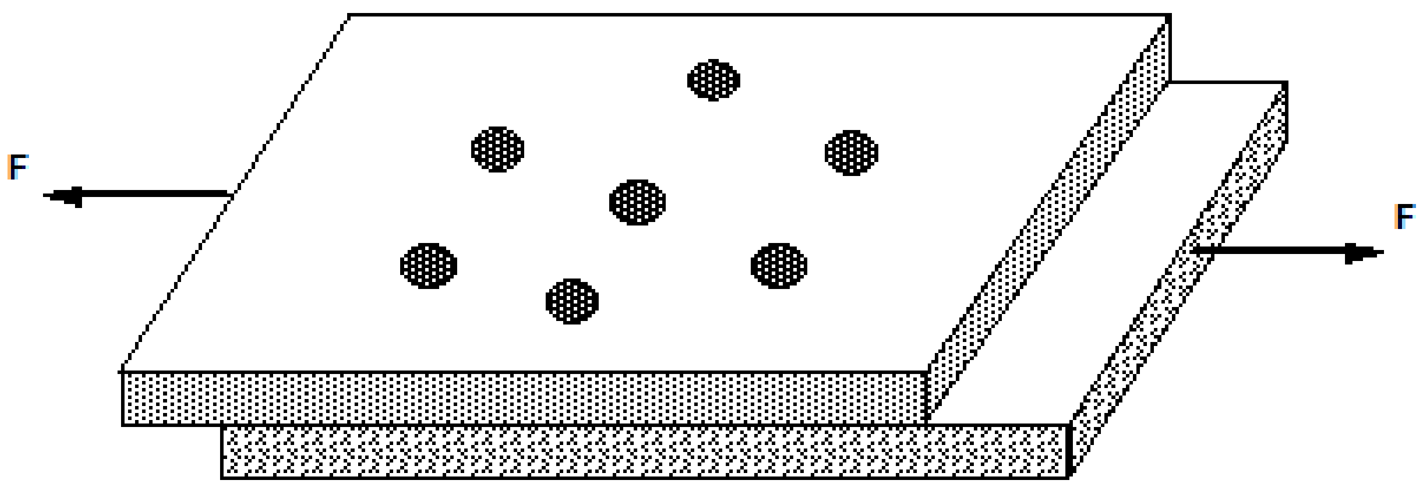
$$F''_1 = F''_4 = 3F/20 \quad ; \quad F''_2 = F''_3 = F/20$$

Example 9.1 A riveted lap joint is shown in the following figure. The diameter of the rivets is 16 mm. The width of the plates is 150 mm and the thickness of the plates is 12 mm. The allowable stresses are as follows:

Rivets: τ= 110 MPa, σ_t = 140 MPa, σ_c = 160 MPa

Plate: τ = 96 MPa, σ_t = 132 MPa, σ_c = 154 MPa

Determine the Strength of the Joint, and the Efficiency of the Joint.

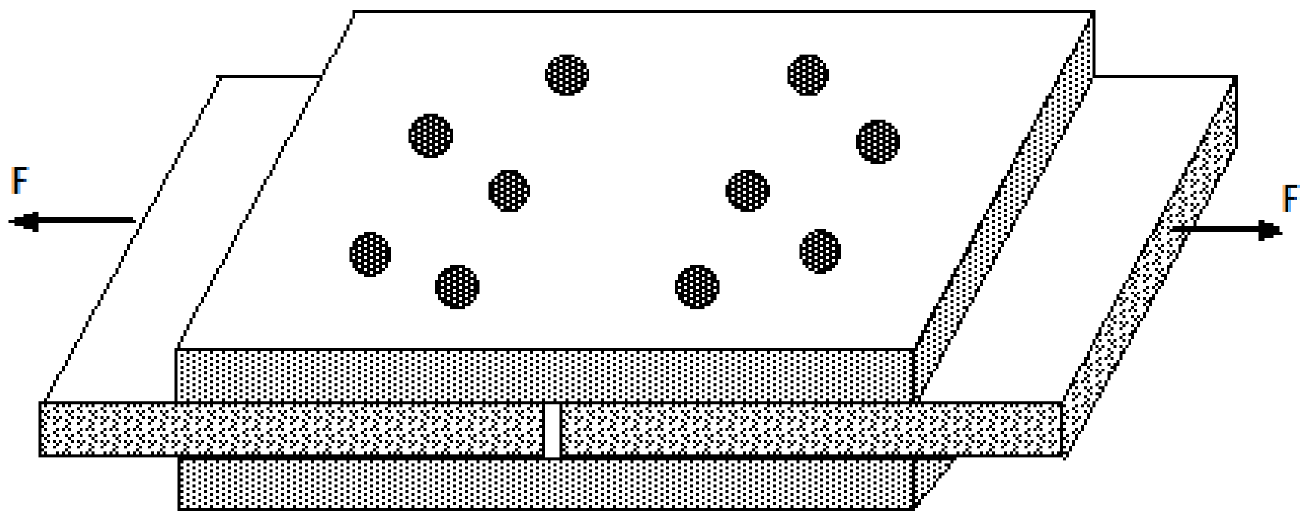


Example 9.2 A riveted butt joint is shown in the following figure. The diameter of the rivets is 16mm. The width of the plates is 150mm, and the thickness of the plates is 15 mm.

Determine the Strength of the Joint, and the Efficiency of the Joint if the allowable stresses are as follows:

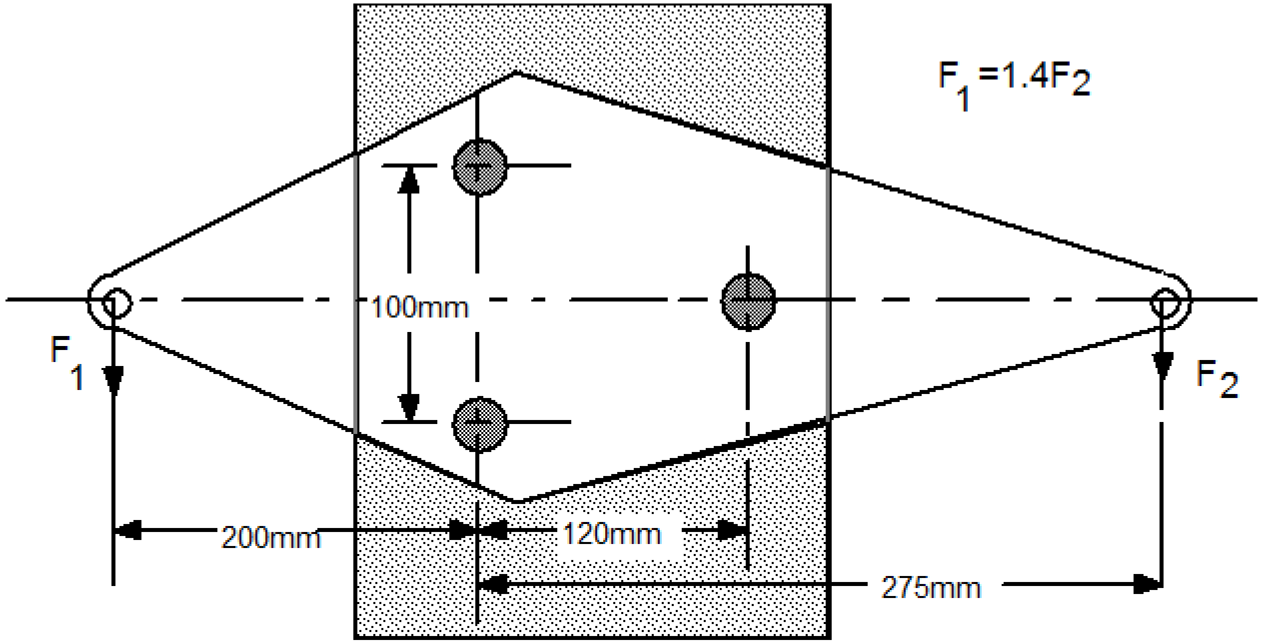
Rivets: τ= 120 MPa, σ_t = 150 MPa, σ_c = 164 MPa

Plate: τ = 108 MPa, σ_t= 138MPa, σ_c = 150 MPa



Example

The plate shown is made of UNS G10350 Cold drawn, and is fastened to an I beam (UNS G10150 Cold drawn, S_y= 320 MPa, S_u= 385 MPa) by three rivets that are made of a steel equivalent to UNS G10100 Cold drawn (S_y= 300 MPa, S_u= 365 MPa). Thickness of the plate (S_y= 460 MPa, S_u= 550 MPa) and of the flanges of the I beam is 15 mm. Diameter of the rivets is 20 mm. What safe loads F_1 and F_2 can be supported by the riveted joint for a factor of safety of 2. Use distortion energy theory of failure. (F_1=1.4F_2)

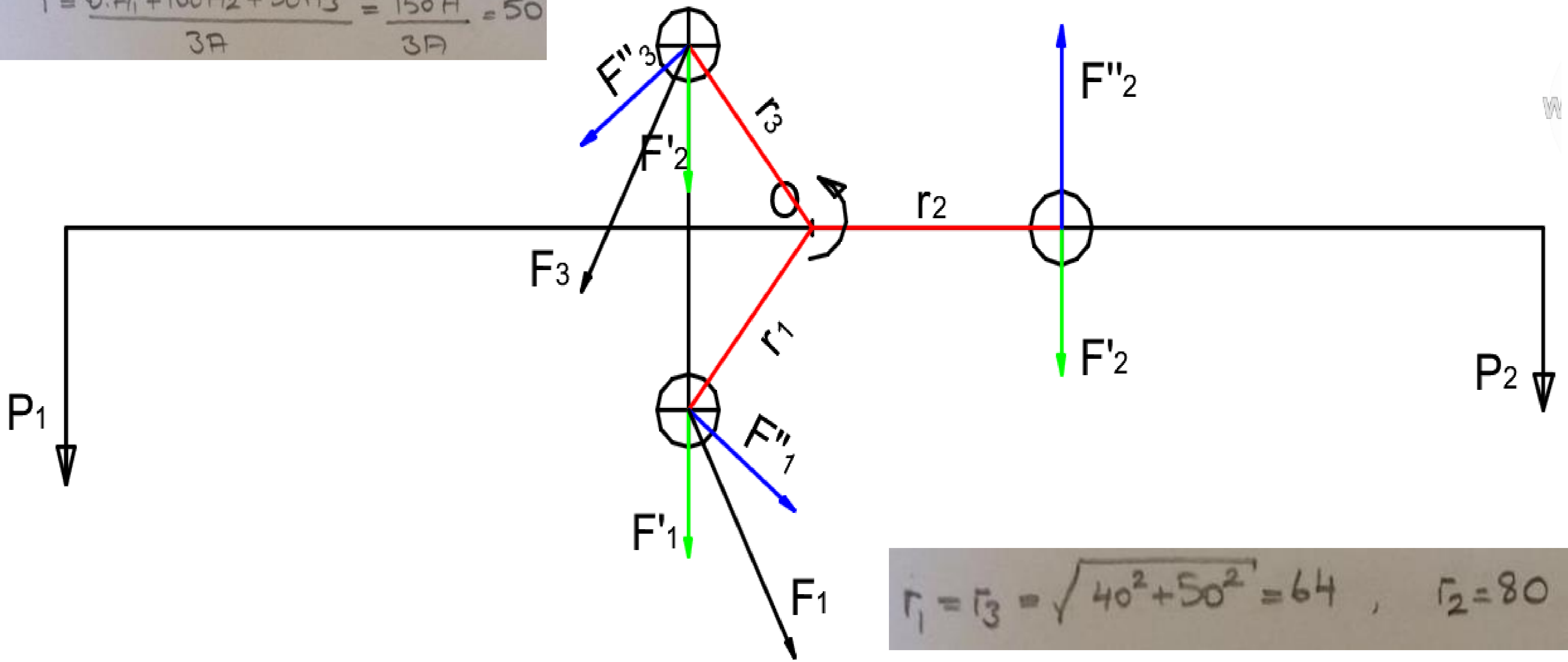


Centroid

$$\bar{X} = \frac{0.A_1 + 0.A_2 + 120.A_3}{A_1 + A_2 + A_3} = \frac{120A}{3A} = 40$$

$$\bar{Y} = \frac{0.A_1 + 100A_2 + 50A_3}{3A} = \frac{150A}{3A} = 50$$

$$F_i' = \frac{F.A_i}{A_1 + A_2 + A_3} \qquad F_i'' = \frac{M.r_i.A_i}{r_1^2.A_1 + r_2^2.A_2 + r_3^2.A_3}$$



$$r_1 = r_3 = \sqrt{40^2 + 50^2} = 64 \quad , \quad r_2 = 80$$

Moment

$$M = P_1.240 - P_2.235 = 240.1,4P_2 - 235P_2$$

$$\ulcorner P_1 = 1,4P_2 \lrcorner$$

$$\Rightarrow M = 101P_2$$

$$F_1'' = F_3'' = \frac{M \cdot r_1 \cdot \cancel{A_1}}{r_1^2 \cancel{A_1} + r_2^2 \cancel{A_2} + r_3^2 \cancel{A_3}}$$

$\ulcorner A_1 = A_2 = A_3 \lrcorner$

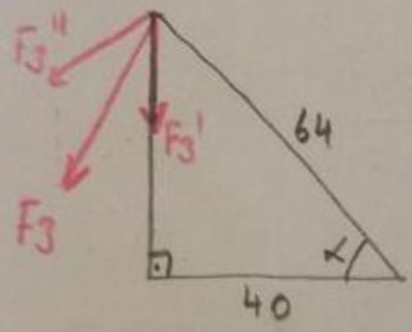
$$= \frac{101 P_2 \cdot 64}{64^2 + 64^2 + 80^2} = 0{,}44\ P_2$$

$$\Rightarrow F_1'' = F_3'' = 0{,}44\ P_2 .$$

$$F_2'' = \frac{M r_2}{r_1^2 + r_2^2 + r_3^2} = \frac{101\ P_2\ 80}{64^2 + 64^2 + 80^2} = 0{,}55\ P_2$$

Net Forces

$$F_1 = F_3 = \sqrt{{F_1'}^2 + {F_1''}^2 + 2F_1' \cdot F_1'' \cdot \cos\theta} \qquad \left[\cos\theta = \frac{40}{64}\right]$$



$$\Rightarrow F_1 = F_3 = P_2\sqrt{(0{,}8)^2 + (0{,}44)^2 + 2 \cdot 0{,}8 \cdot 0{,}44 \cdot 0{,}625}$$

$$\Rightarrow \boxed{F_1 = F_3 = 1{,}136\, P_2}$$

$$F_2 = F_2' - F_2'' = 0{,}8 P_2 - 0{,}55 P_2 = 0{,}25 P_2$$

$1{,}136\, P_2 > 0{,}25\, P_2 \Rightarrow$ 1 or 3 are critical rivets.

thus; analysis will be based on for either rivet 1 or rivet 3. Say rivet 1.

1- Shearing of Rivets

$$\tau = \frac{F}{A} = \frac{1,136\,P_2}{\frac{\pi \cdot 20^2}{4}} = 0,00361\,P_2 \text{ MPa}$$

DET:

$$S_{sy} = 0,577 \cdot 300 = 173,1 \text{ MPa}$$

$$\Rightarrow n = \frac{S_{sy}}{\tau} \Rightarrow 2 = \frac{173,1}{0,00361\,P_2}$$

$$\Rightarrow P_2 = 23975 \text{ N} \qquad P_1 = 1,4 \cdot 23975 = 33565 \text{ N}$$

From bearing of I beam;

$$\tau = \frac{F}{t.D} = \frac{S_y}{n}$$

$$\frac{1{,}136 P_2}{15.20} = \frac{320}{2} \Rightarrow P_2 = 42253{,}5\ N$$

$$P_1 = 59154{,}9\ N$$

Bearing (crushing of the rivets) yields;

$$\tau = \frac{F}{t.d} = \frac{S_y}{n}$$

$$\Rightarrow \frac{1{,}136 P_2}{15.20} = \frac{300}{2} \Rightarrow P_2 = 39613\ N$$

$$P_1 = 55\,458\ N$$

Hence, shearing of the rivets governs the design and;

$P_1 = \underline{33\,565}\ N$ $P_2 = \underline{23975}\ N.$

Allowable force $\Rightarrow$ we have to choose the lowest force condition