Design of Knuckle Joint

• A knuckle joint is used to connect two rods which are under the action of tensile load, when small amount of flexibility or angular moment is necessary.
• The line of action of load is always axial.
• The knuckle joint consist of three major parts.
  a) Single eye b) Double eye c) Knuckle pin
• The single eye is formed at the one end and double eye is formed at the other end of the rod.
• The single eye fit into fork or double eye, both the parts are connect by pin inserted through eye.
• The knuckle pin has a head at one end and collar and taper pin or split pin at other end.
• The ends of the rod are of octagonal forms for improving the gripping at the time of repairs.

Knuckle Joint Video
• **Function of Split pin** –
It holds collar and prevent lifting or ejecting the knuckle pin from the joint.

**Applications of knuckle Joint** –
1. Tie rod of roof truss
2. Link of roller chain
3. Tension link in bridge structure
4. Tie rod joint of jib crane.
**Knuckle joint**

Two or more rods subjected to tensile and compressive forces are fastened together.

Their axes are not in alignments but meet in a point.

The joint allows a small angular moment of one rod relative to another.

It can be easily connected and disconnected.

Applications: Elevator chains, valve rods, etc.
Knuckle joint
• Let \( P \) = tensile load acting on rod
\( d \) = diameter of rod
\( d_1 \) = diameter of pin
\( d_2 \) = outer diameter of eye.
\( d_3 \) = diameter of knuckle pin head & collar.
\( t \) = thickness of single eye.
\( t_1 \) = thickness of fork.
\( t_2 \) = thickness of pin head.
Empirical Relations

Diameter of pin = $d_1 = d$

Outer diameter of eye = $d_2 = 2d$

Diameter of knuckle pin head & collar = $d_3 = 1.5d$

Thickness of single eye = $t = 1.25d$

Thickness of fork = $t_1 = 1.75d$

Thickness of pin head $t_2 = 0.5d$
Design Procedure

1) Failure of rod in tension

\[ \sigma_t = \frac{P}{\frac{\pi}{4} d^2} \quad (1) \]

*From this equation d is obtained*
2) Failure of knuckle pin

a) Failure of knuckle in double shear.

\[ \tau = \frac{P}{2 \times \frac{\pi}{4} d_1^2} \]  

\( (2) \)

*From this equation diameter of knuckle pin \((d_1)\) is obtained*

This assume that, there is no slack or clearance, but in actual practice pin is loose in fork to permit angular moment of one with respect to other. So it is subjected to bending moment in addition to shear
b) Considering bending failure of knuckle pin
\[ M = \frac{P}{2} \left( \frac{t_1}{3} + \frac{t}{2} \right) - \frac{P}{2} \times \frac{t}{4} \]
\[ = \frac{P}{2} \left( \frac{t_1}{3} + \frac{t}{2} - \frac{t}{4} \right) \]
\[ = \frac{P}{2} \left( \frac{t_1}{3} + \frac{t}{4} \right) \]

Section modulus \( Z = \frac{\pi}{32} d_1^3 \)

\[ \therefore \sigma_t = \frac{M}{Z} = \frac{P}{2} \left( \frac{t_1}{3} + \frac{t}{4} \right) - \frac{\pi}{32} d_1^3 \]

\[ \text{(3)} \]

From this equation \( d_1 \) is obtained
3) Failure of single eye end in tension

- Single eye end may tear off due to tension.

\[ \sigma_t = \frac{P}{(d_2 - d_1) \times t} \quad (4) \]

From this equation \((\sigma_t)\) for the single eye end may be checked.
4) Failure of Single eye end in shearing

- Considering the shear failure of single eye end.

\[ \tau = \frac{P}{(d_2 - d_1) \times t} \quad (5) \]

*From this equation shear stress (\(\tau\)) for single eye end may be checked.*
5) Failure of single eye end in crushing

- Considering the crushing failure of single eye end.

\[
\sigma_{cr} = \frac{P}{d_1 \times t} \quad \text{(6)}
\]

*From this equation crushing stress \( \sigma_{cr} \) for the single eye or pin may be checked.*
6) Failure of forked end in tension

- Considering the tensile failure of double eye of forked end.

\[ \sigma_t = \frac{P}{(d_2 - d_1) \times 2t_1} \]  \hspace{1cm} (7)

*From this equation tensile stress \((\sigma_t)\) for the forked end may be checked.*
7) Failure of forked end in shear

- Considering the shear failure of forked end.

\[ \tau = \frac{P}{(d_2 - d_1) \times 2t_1} \]  

*From this equation shear stress (\( \tau \)) for the forked end may be checked.*
8) Failure of forked in crushing

- Considering the crushing failure of forked end.

\[ \sigma_{cr} = \frac{P}{d_1 \times 2t_1} \quad (9) \]

*From this equation, the crushing stress in the forked may be checked.*
1. First of all, find the diameter of the rod by considering the failure of the rod in tension. We know that tensile load acting on the rod,

\[ P = \frac{\pi}{4} \times d^2 \times \sigma_t \]

where

- \( d \) = Diameter of the rod, and
- \( \sigma_t \) = Permissible tensile stress for the material of the rod.

2. After determining the diameter of the rod, the diameter of pin (\( d_1 \)) may be determined by considering the failure of the pin in shear. We know that load,

\[ P = 2 \times \frac{\pi}{4} \left( d_1 \right)^2 \tau \]

A little consideration will show that the value of \( d_1 \) as obtained by the above relation is less than the specified value (i.e. the diameter of rod). So fix the diameter of the pin equal to the diameter of the rod.

3. Other dimensions of the joint are fixed by empirical relations as discussed in Art. 12.13.

4. The induced stresses are obtained by substituting the empirical dimensions in the relations as discussed in Art. 12.14.

In case the induced stress is more than the allowable stress, then the corresponding dimension may be increased.
<table>
<thead>
<tr>
<th>Sr. No.</th>
<th><strong>Knuckle Joint</strong></th>
<th><strong>Cotter Joint</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>It takes only tensile load</td>
<td>It takes tensile as well as compressive load.</td>
</tr>
<tr>
<td>2</td>
<td>It allows angular movement between rods</td>
<td>It can not allow angular movement</td>
</tr>
<tr>
<td>3</td>
<td>It is subjected to baring failure.</td>
<td>It is not subjected to bearing failure.</td>
</tr>
<tr>
<td>4</td>
<td>No taper or clearance provided on knuckle pin.</td>
<td>Taper or clearance will be provide on cotter.</td>
</tr>
<tr>
<td>5</td>
<td>Ex – tie bar, links od bicycle chain, joint for rail shifting mechanism</td>
<td>Ex- cotter foundation bolt, joining of two rods with a pipe, joining piston rod with c/s head.</td>
</tr>
</tbody>
</table>
Example 12.7. Design a knuckle joint to transmit 150 kN. The design stresses may be taken as 75 MPa in tension, 60 MPa in shear and 150 MPa in compression.