

# KEYS, COTTERS & KNUCKLE JOINTS

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# Stresses in Key



## Crushing Stress Analysis

Crushing stress acts on the key sides due to compressive force from hub and shaft. It is critical when key height is small relative to length.

$$\text{Crushing Stress: } \sigma_c = 4T / (d \times h \times L)$$

Where  $h$  = key height. Condition:  $\sigma_c \leq \sigma_{c\_allowable}$ .

Factor of Safety (FOS) = 2 to 3 for static loads; higher for dynamic/impact loading.

A key transmits torque between shaft and hub. Two primary failure modes govern key design: shear failure along the key width and crushing (compressive) failure on the key sides. Both stresses must be evaluated against allowable limits.

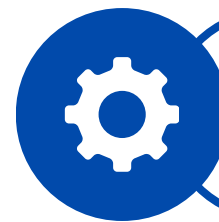
## Shear Stress Analysis

$$\text{Shear Stress: } \tau = 2T / (d \times w \times L)$$

Where  $T$  = torque,  $d$  = shaft dia,  $w$  = key width,  $L$  = key length.

Design condition:  $\tau \leq \tau_{allowable}$  ( $S_{sy} / FOS$ ).

# Cottered Joints



## Definition & Applications

A cottered joint is a temporary fastening used to connect two rods or bars subjected to axial tensile or compressive forces.

Used in connecting piston rod to crosshead in steam engines.

Applied in pump rods, valve rods, and structural tie rods.

Types: Sleeve & cotter, Spigot & socket, Gib & cotter joints.



## Advantages & Limitations

Advantages: Simple design, easy assembly and disassembly, reliable load transfer, cost-effective for axial loading.

Limitation: Not suitable for rotating shafts or dynamic/torsional loads.

Cotter may loosen under vibration; taper and locking arrangements are required.

Stress concentrations at cotter slot require careful design and material selection.

# Spigot and Socket Joint



## Design Procedure

A spigot and socket cotter joint connects two rods under tensile or compressive loads. The spigot fits into the socket and is secured by a cotter pin passing through both.

Tensile failure of spigot end:  $P = (\pi/4)(d_2^2 - d_1^2) \times \sigma_t$ , where  $d_2$  = spigot collar dia,  $d_1$  = cotter slot width.

Socket end tensile stress:  $P = (d_4^2 - d_3^2) \times (\pi/4) \times \sigma_t$ ;  $d_3$  = socket inner dia,  $d_4$  = socket outer dia.

Standard proportions:  $d_2 = 1.5d$ , socket outer dia =  $2.4d$ , cotter taper = 1 in 24 for self-locking.



## Stress Analysis

Three critical stresses are evaluated during design: tensile stress in the rod, shear stress in the cotter, and crushing (bearing) stress between cotter and rod surfaces.

Shear stress in cotter:  $\tau = P / (2 \times b \times t)$ , where  $b$  = width of cotter,  $t$  = thickness of cotter.

Crushing stress:  $\sigma_c = P / (d \times t)$ ; where  $d$  = diameter of spigot or rod,  $t$  = cotter thickness at bearing area.

Design check: All computed stresses must be  $\leq$  allowable stress values for the chosen material (mild steel or alloy steel).

# Sleeve and Cotter Joint

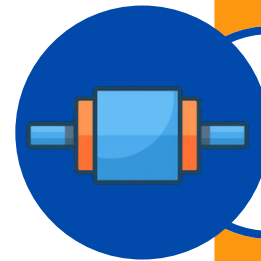
Design is checked against multiple failure modes to ensure joint integrity under axial tensile or compressive loads applied through the connected rods.

## Failure Modes and Stress Equations

Tensile failure of rod:  $\sigma_t = P / (\pi d^2/4)$ ; Shear of cotter:  $\tau = P / (2bt)$

Crushing of cotter:  $\sigma_c = P / (dt)$ ; Shear of sleeve end:  $\tau = P / (2 \times D \times a)$

All dimensions are derived iteratively based on load  $P$  and allowable stresses.



## Construction Details

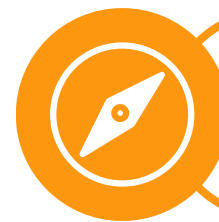
A sleeve and cotter joint connects two rods end-to-end using a hollow cylindrical sleeve and two cotters. The rods fit into the sleeve from both ends and are locked by cotters passed through slots cut in the sleeve and rods.

Sleeve outer dia:  $D = 2d$ ; Inner dia =  $d$  (rod dia)

Cotter thickness:  $t = d/4$ ; Width:  $b = 1.25d$

Sleeve length:  $L = 8d$  (approx. design standard)

# Gib and Cotter Joints



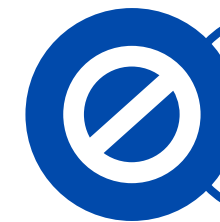
## Gib and Cotter Design

A gib and cotter joint is used to connect two rods subjected to tensile or compressive forces. The gib prevents the cotter from slipping and provides a bearing surface.

Purpose of gib: provides wider bearing area and prevents cotter from buckling or bending during assembly.

Design considerations: taper of cotter (1:24 to 1:48), width and thickness of gib, and bearing pressure on socket.

Assembly and disassembly: the tapered cotter allows easy tightening and removal, enabling quick joint adjustment.



## Stress Analysis

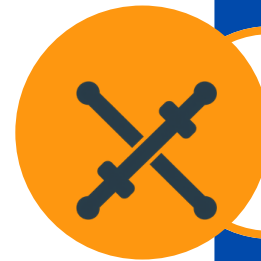
Stresses induced in gib and cotter joints must be carefully analyzed to ensure safe load transmission under both static and dynamic conditions.

Shear stress in cotter: calculated based on double shear across the cotter cross-section area.

Crushing stress in gib and cotter: determined by the projected area in contact with the rod end and socket.

Tensile stress in rod: the rod cross-section at the cotter slot must withstand the full applied tensile load safely.

# Knuckle Joints



## Applications

Knuckle joints permit angular movement in one plane and are widely used where rods must pivot relative to each other under tensile loading conditions.

Tie rods and tension links in structures.

Valve mechanisms and lever systems.

Suspension links, tractor steering, and crane hooks.

A knuckle joint is a mechanical joint used to connect two rods subjected to tensile loads. It allows angular movement between the connected members and transmits axial or tensile force effectively.

## Key Components

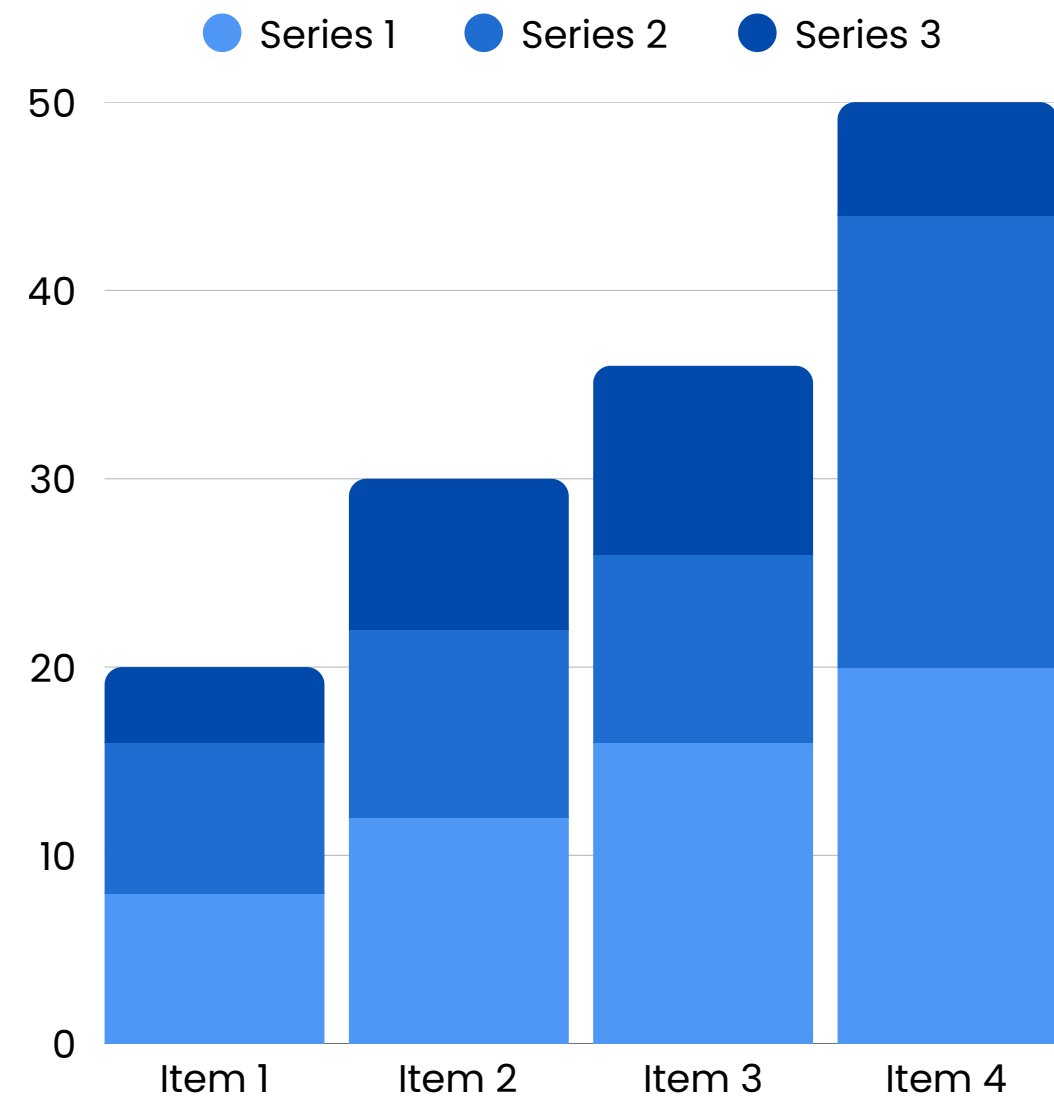
Eye end: Single eye formed at one rod end.

Fork end: Double eye (forked) formed at the other rod.

Knuckle pin: Passes through eye and fork to connect them.

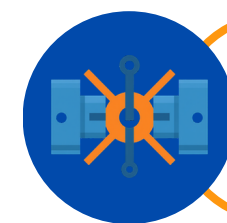


# Knuckle Joint: Stress Analysis



## Stresses in Knuckle Joint Components:

- Tensile stress in rod:  $\sigma_t = P / ((\pi/4) \times d^2)$
- Shear stress in pin:  $\tau = P / (2 \times (\pi/4) \times d^2)$
- Crushing stress in eye:  $\sigma_c = P / (d \times t)$
- Crushing stress in fork:  $\sigma_c = P / (d \times 2t_1)$



## Stress Analysis

## Dimensional Ratios & Design Equations:

- Pin dia:  $d = d_0$  (rod dia); Eye thickness:  $t = 1.25d$
- Fork thickness:  $t_1 = 0.75d$ ; Eye outer dia:  $D = 2d$
- Design condition: Induced stress  $\leq$  Allowable stress
- Check all modes: tension, shear & crushing
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# THANK YOU

Questions & Discussion Welcome

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