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# Design and Analysis of Knuckle Joint for Tensile Load Applications

**Mr. B.S. Swami[1]**

*[1] Mr. B.S. Swami (Lecturer in Mechanical Engineering Department, SPM Polytechnic, Kumathe, Solapur)*

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**Abstract -** *A knuckle joint is a mechanical joint used to connect two rods subjected to tensile loads. It permits limited angular movement between the rods while transmitting axial force efficiently. This paper presents the design methodology of a knuckle joint considering various mechanical parameters such as tensile strength, shear strength, and crushing strength of materials. The design calculations are performed based on standard design procedures to ensure safety and reliability. The study includes determination of dimensions of rod, pin, eye, fork, and collar. The proposed design ensures that the joint is safe under different modes of failure such as tearing, shearing, and crushing. The results demonstrate that proper material selection and design considerations significantly improve the performance and durability of the joint. This work is useful for students and engineers involved in machine design and mechanical applications.*

***Key Words*: Knuckle Joint, Machine Design, Tensile Load, Shear Stress, Mechanical Joint, Design Analysis, Failure Modes**

## 1.INTRODUCTION

A knuckle joint is widely used in mechanical applications to connect two rods that are subjected to tensile loads. It allows slight angular movement and is commonly used in structures such as tie rods, suspension systems, and valve mechanisms. The joint consists of components like eye, fork, pin, and collar. The primary function of a knuckle joint is to transmit tensile force while allowing flexibility in alignment. It is designed to withstand various stresses such as tensile stress, shear stress, and bearing stress.

### 1.1 Applications of Knuckle Joint

Tie rods in bridges, Suspension links, Valve mechanisms and Agricultural machinery

### 1.2 Objectives of Study

i. To design a safe knuckle joint
ii. To determine dimensions of different components
iii. To analyze failure modes
iv, To ensure strength and reliability

## 2. DESIGN METHODOLOGY

The design of a knuckle joint is carried out to safely transmit tensile load between two rods while allowing slight angular movement. The methodology involves systematic calculation of dimensions based on strength criteria such as tensile, shear, and crushing stresses.

### 2.1 Assumptions

The following assumptions are considered during design:
i. The load acting on the joint is purely axial (tensile).
ii. The material used is homogeneous and isotropic.
iii. The stresses induced are within permissible limits.
iv. Effects of stress concentration are neglected for simplicity.

### 2.2 Applications:

i. Joints between tie rods in roof trusses.
ii. Joints between the links of a suspension bridge.
iii. Joints in valve mechanism of reciprocating engine.
iv. Fulcrum for the levers.
v. Joints between the links of a bicycle chain.

### 2.3 Design of Knuckle Joint:

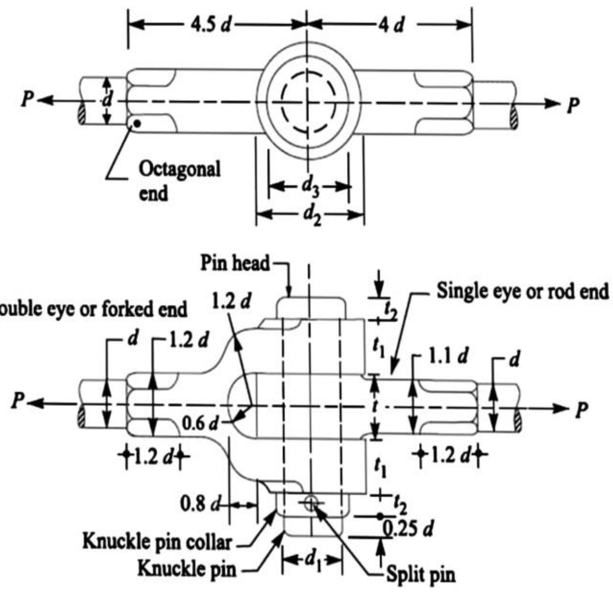


**Fig. Knuckle Joint**

Let,

$d$ = Diameter of Rod
$d_1$ = Diameter of Knuckle Pin
$d_2$ = Outer Diameter of Single or Double Eye
$d_3$ = Diameter of Knuckle Pin Head and Collar
$t$ = Thickness of Single Eye
$t_1$ = Thickness of Fork or Double Eye
$t_2$ = Thickness of Knuckle Pin Head or Collar Pin Head
$P$ = Load Carries by End of Rod

**2.3 Design Failures**

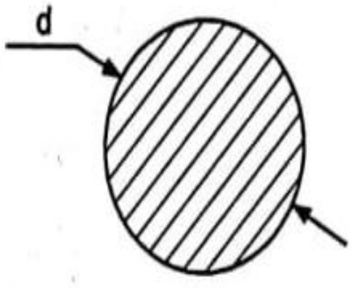


**Fig. Failure of Rod in Tension**

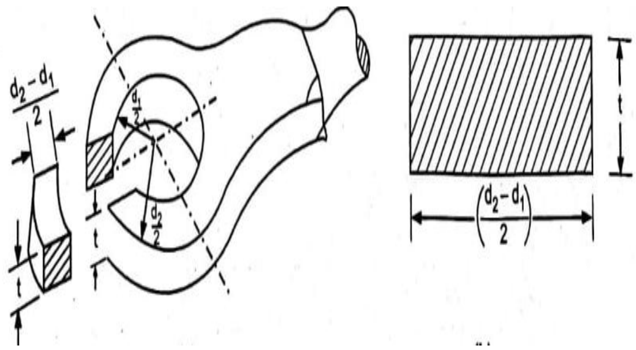

**Fig. Failure of Single Eye in Double Shear**

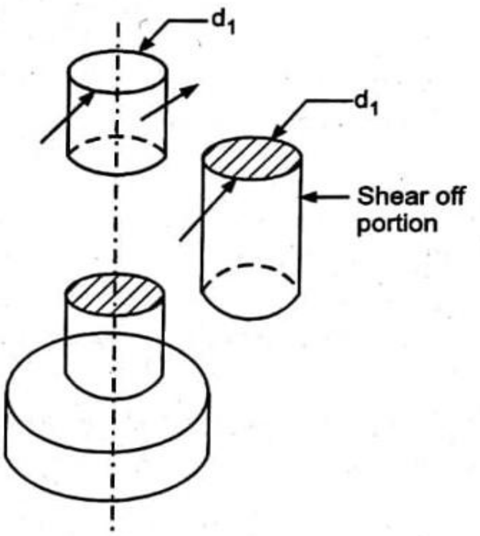


**Fig. Failure of Knuckle Pin in Double Shear**

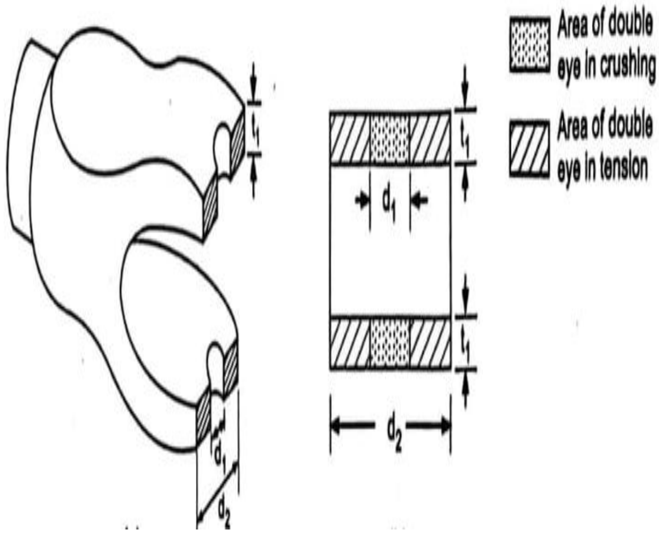


**Fig. Failure of Double Eye in Tension and Crushing**

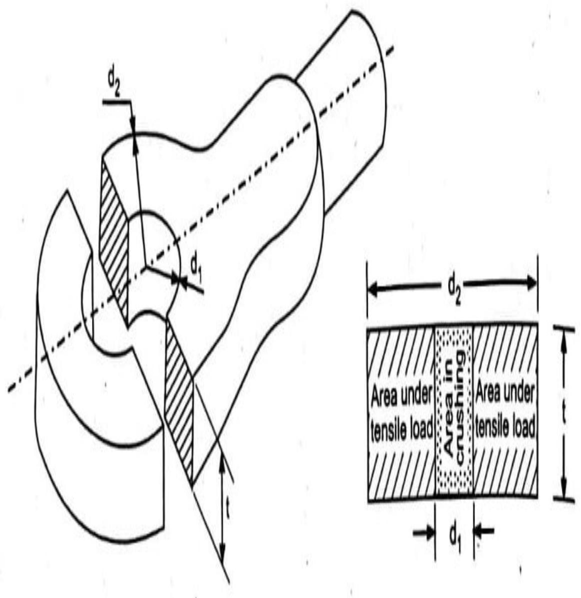


**Fig. Failure of Single Eye in Tension**

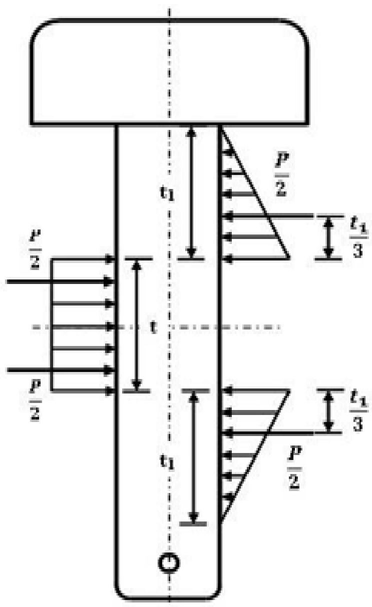

**Fig. Failure of Knuckle Pin in Bending**

### 2.4 Given Data

Load acting on joint, P = 50 kN
Permissible tensile stress, $\sigma_t$ = 75 MPa
Permissible shear stress, τ = 60 MPa
Permissible crushing stress, σc = 120 MPa

### 2.5 Design of Rod Diameter (d)

The rod is subjected to tensile stress. Therefore,

$$P = \frac{\pi}{4} d^2 \sigma_t$$

By Rearranging,

$$d = \sqrt{\frac{4P}{\pi \sigma_t}}$$

$$d = \sqrt{\frac{4 \times 50 \times 10^3}{\pi \times 75}}$$

$$d \approx 29.1 \text{ mm} \approx 30 \text{ mm}$$

### 2.6 Design of Pin Diameter (dp)

The pin is subjected to shear. Considering double shear:

$$P = 2 \times \frac{\pi}{4} d_p^2 \tau$$

$$d_p = \sqrt{\frac{2P}{\pi \tau}}$$

$$d_p = \sqrt{\frac{2 \times 50 \times 10^3}{\pi \times 60}}$$

$$d_p \approx 23 \text{ mm} \approx 25 \text{ mm}$$

### 2.7 Design of Eye Thickness (t)

The eye is subjected to crushing and tearing.

Empirical relation:

$$t = 1.25d$$

$$t = 1.25 \times 30 = 37.5 \approx 38 \text{ mm}$$

### 2.8 Design of Fork Thickness ($t_1$)

Each fork arm carries half the load:

$$t_1 = 0.75d$$

$$t_1 = 0.75 \times 30 = 22.5 \approx 23 \text{ mm}$$

### 2.9 Design of Pin in Crushing

$$P = d_p \times t \times \sigma_c$$

Check whether induced stress is less than permissible value.

### 2.10 Design of Pin in Bending

The pin is subjected to bending due to clearance between eye and fork.

Maximum bending moment:

$$M = \frac{P}{2} \times \left(\frac{t}{2} + \frac{t_1}{3}\right)$$

Check bending stress:

$$\sigma_b = \frac{32M}{\pi d_p^3}$$

### 2.11 Failure Modes Considered

The knuckle joint is checked against the following failures:
Tensile failure of rod
Shear failure of pin
Crushing failure of pin and eye
Tearing failure of eye
Shear failure of fork
Bending failure of pin

### 2.12 3D View of Knuckle Joint

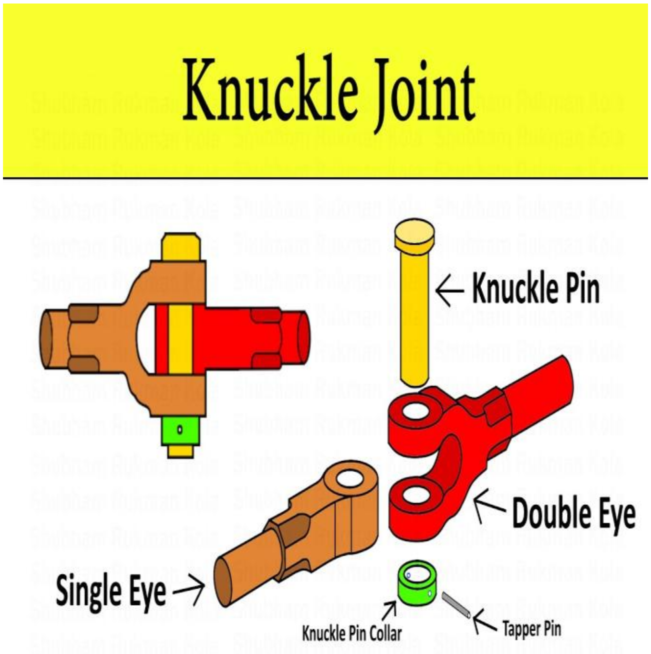


**Fig. Details and Assembly of Knuckle Joint**

### 2.13 Actual Model of Knuckle Joint

**Fig. Actual Model of Knuckle Joint**

## 3. Result and Discussion

The calculated dimensions ensure that the knuckle joint is safe under all loading conditions. The stresses induced in different components are within permissible limits. Proper factor of safety has been considered to avoid failure.

The design confirms that:

i.Pin is safe in shear

ii. Rod is safe in tension

iii. Eye and fork are safe in crushing

## 4. Conclusion

The design of the knuckle joint has been successfully completed based on standard mechanical design procedures. The joint is capable of safely transmitting the given load without failure. Proper consideration of different failure modes ensures reliability and durability. This study highlights the importance of accurate design and material selection in machine elements.

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## BIOGRAPHIES

Mr. B.S. Swami
(Lecturer in Mechanical Engineering Department)
SPM Polytechnic, Kumathe, Solapur