Riveted, Welded & Bolted Joints

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Introduction

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Course: Design of Machine Elements
Topic: Riveted, Welded and Bolted Joints
This course covers the analysis and design of riveted joints, welded joints, and bolted joints including methods of failure, strength equations, efficiency, and eccentric loading conditions.

Types of Joints

Riveted Joints

Welded Joints

Bolted Joints

Riveted Joints

Definition & Basics

A riveted joint is a permanent fastening used to join two or more plates or structural members using rivets. A rivet is a short cylindrical bar with a head, inserted through holes in the parts to be joined and then hammered to form a closing head. Riveted joints are widely used in boilers, pressure vessels, bridges, and aircraft structures where a strong, leak-proof connection is required.

Applications & Types

Riveted joints are classified as Lap Joints and Butt Joints based on arrangement. They are used in structural steelwork, ship hulls, and storage tanks. Key parameters include pitch (p), diameter of rivet (d), and plate thickness (t). Types of riveting patterns include single riveted, double riveted, chain riveted, and zigzag riveted configurations, each offering different strength and efficiency characteristics.

Methods of Failure

Shearing of Rivets

Tearing of Plate

Crushing of Rivet

Strength Equations

Shear Strength of Riveted Joints: The shear strength is the resistance offered by rivets against shearing forces. For a single shear joint: $P_s = n \times (\pi/4) \times d^2 \times \tau$, where n = number of rivets, d = diameter of rivet, τ = permissible shear stress. For double shear: $P_s = n \times 2 \times (\pi/4) \times d^2 \times \tau$. The rivet diameter is selected based on plate thickness using empirical relation: $d = 6\sqrt{t}$

Bearing (Crushing) Strength of Riveted Joints: Bearing strength resists the crushing of rivets or plates under compressive load. $P_b = n \times d \times t \times \sigma_c$, where n = number of rivets, d = rivet diameter, t = plate thickness, σ_c = permissible crushing stress. Tensile strength of plate: $P_t = (p - d) \times t \times \sigma_t$, where p = pitch, σ_t = permissible tensile stress. The least of Ps, Pb, Pt governs joint strength.

Efficiency of Riveted Joints

Efficiency (η) = Strength of riveted joint / Strength of solid plate

Key Failure Modes Considered:

- Tearing of plate between rivets
- Shearing of rivets
- Crushing of rivets or plate
- Tearing at edge of plate

Efficiency Formula:

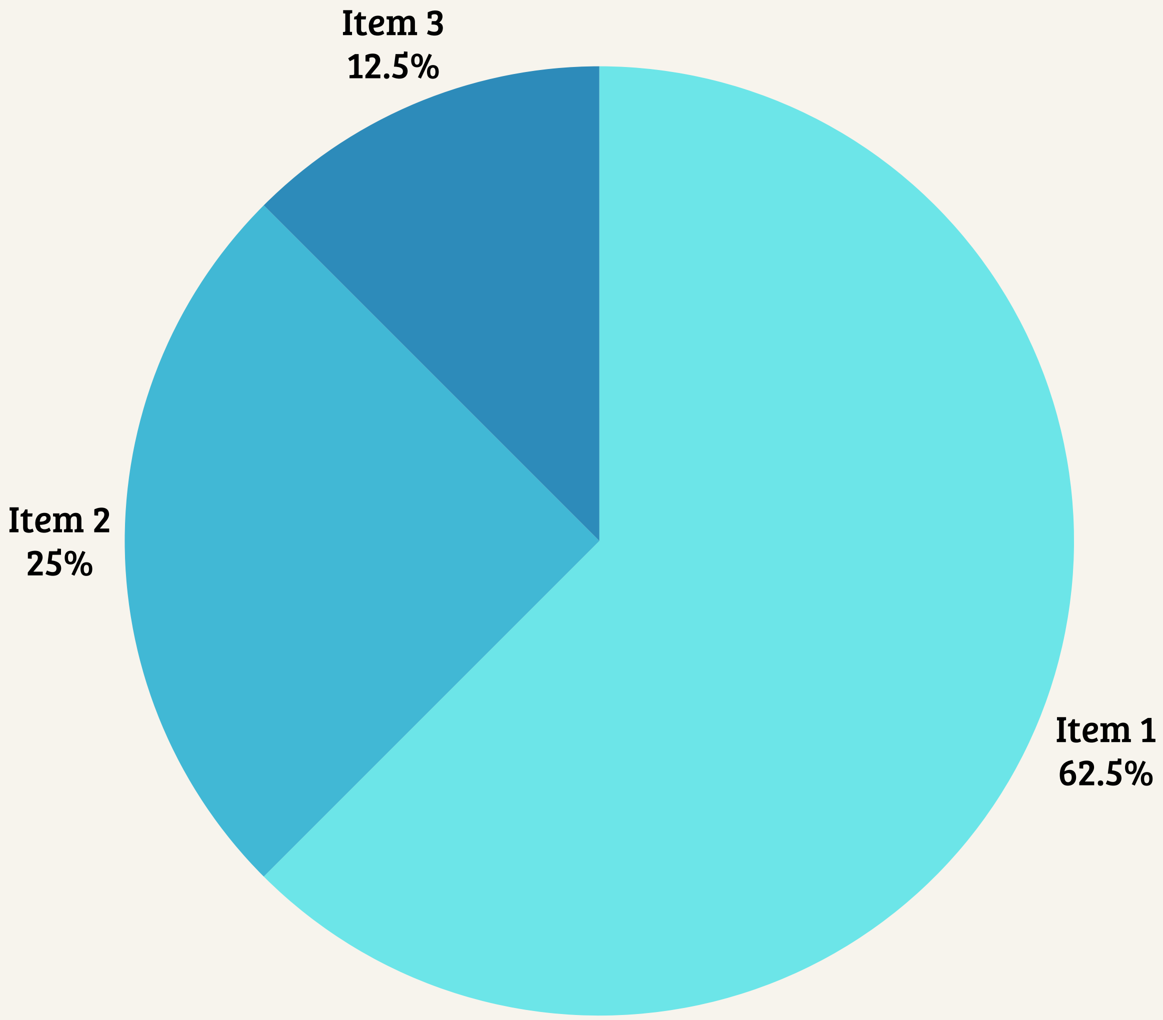
$\eta = (p - d) \times t \times \sigma t / (p \times t \times \sigma t)$

Where: p = pitch, d = rivet dia,

t = thickness, σt = tensile stress

Typical Efficiency Values:

- Single riveted lap joint: 50–60%
- Double riveted lap joint: 60–72%
- Single riveted butt joint: 55–60%
- Double riveted butt joint: 70–83%



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Eccentrically Loaded Riveted Joints

When a load is applied eccentrically on a riveted joint, it creates both a direct shear force and a turning moment (torque) about the centroid of the rivet group. The direct shear is shared equally among all rivets, while the moment induces additional shear forces proportional to each rivet's distance from the centroid. The resultant shear on each rivet is found by vector addition of direct and moment-induced shear components.

Design Procedure: (1) Locate the centroid of the rivet group. (2) Calculate direct shear load per rivet = P/n. (3) Determine the turning moment $M = P \times e$, where e is the eccentricity. (4) Compute secondary shear force on each rivet = $M \times r / \Sigma r^2$. (5) Find resultant shear by vector combination. (6) The most stressed rivet (farthest from centroid) governs the design. Ensure resultant shear ≤ permissible shear stress × rivet cross-section area.

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Welded Joints

Types of Welded Joints

Welded joints are permanent joints formed by fusion of metals using heat. Common types include Butt Joints (used for plates in the same plane), Lap Joints (overlapping plates joined by fillet welds), T-Joints (plates at right angles), Corner Joints, and Edge Joints. Welded joints offer high strength, leak-proof connections, and are widely used in pressure vessels, bridges, and machine frames.

Fillet Welds – Overview

Fillet welds are triangular cross-section welds used to join two surfaces at approximately right angles. Key parameters: Throat thickness ($t = 0.707 \times$ leg size 'h'), Fillet weld size, and Length of weld. Fillet welds resist shear stress along the throat. Used extensively in lap joints and T-joints. Design strength: $P = 0.707 \times h \times l \times \tau$, where l = weld length and τ = permissible shear stress.

Design of Fillet Welds

Axial Loads

Fillet welds under axial loads carry tensile or compressive forces parallel to the weld axis. Throat area = 0.707 x size x length. Shear stress: $\tau = P / (0.707 \times s \times l)$. Both parallel and transverse fillet welds are used. Transverse welds are stronger than parallel welds. Safe load capacity depends on permissible shear stress of weld material.

Circular Fillet Welds

Circular fillet welds resist bending and torsional moments. Under bending: $\sigma = M / (0.707 \times s \times \pi \times r^2)$. Under torsion: $\tau = T \times r / (0.707 \times s \times 2\pi \times r^2)$. Combined loading uses vector addition of stresses. Throat section treated as a line for analysis. Used in shafts, flanges, and pipe connections requiring rotational load resistance.

Circular Fillet Welds

Circular Fillet Welds Under Bending:

- A circular fillet weld is treated as a line; throat area = $0.707 \times t \times \pi \times d$
- Bending moment M induces a bending stress: $\sigma_b = M / Z_w$, where $Z_w = \pi d^2 / 4$ (section modulus of weld group)
- The maximum bending stress acts at the top and bottom of the circular weld
- Design condition: resultant stress $\leq$ allowable shear stress of weld material

Circular Fillet Welds Under Torsion:

- Torsional moment T causes shear stress: $\tau = T \times r / J_w$, where $J_w = \pi d^3 / 4$ (polar moment of weld line)
- The shear stress acts perpendicular to the radius at every point along the weld
- For combined bending and torsion, resultant stress = $\sqrt{\sigma_b^2 + \tau^2} \leq$ allowable stress
- Weld size (throat) is determined from: t = Force / (allowable stress × effective weld length)

Analysis

Welded Joints Under Eccentric Loading

Eccentric loading occurs when the load does not pass through the centroid of the weld group, creating both direct shear stress and additional shear stress due to the turning moment. The resultant stress is obtained by vector addition of direct shear and torsional shear components at the critical weld location.

Design Approach & Analysis

The weld group centroid is located first, then the polar moment of inertia (J) is calculated. Direct shear: $\tau_1 = P/A\_w$. Torsional shear: $\tau_2 = M \cdot r/J$, where $M = P \times e$ (eccentricity). Resultant stress: $\tau\_res = \sqrt{(\tau_1^2 + \tau_2^2 + 2\tau_1\tau_2\cos\theta)} \leq \tau\_allowable$. Safe weld size is determined accordingly.

Bolted Joints

Design of Bolts with Pre-stresses

Pre-stressed bolts are designed to clamp joint members together, preventing separation under load. The pre-stress (initial tension) is introduced by tightening the bolt. Design involves calculating the required bolt diameter based on the combined effect of pre-stress and external load. The resultant load on the bolt is the sum of pre-stress and the fraction of external load carried by the bolt, ensuring joint integrity.

Joints Under Eccentric Loading

Eccentrically loaded bolted joints experience both direct shear and additional shear due to the turning moment. The critical bolt (farthest from centroid) carries the maximum resultant shear force. Design ensures the bolt can withstand this combined loading. Locking devices such as lock nuts, split pins, and spring washers prevent loosening. Bolts of uniform strength are designed by reducing the shank diameter to match the core diameter, improving fatigue resistance.

Bolted Joint Design

Locking Devices

Bolts of Uniform Strength

Applications & Design

Thank You!
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