SAE Bolt Torque / Preload Calculator

1. Overview

This module computes bolt preload, proof load ratios, tensile load ratios, and nut factors for standard UNC and UNF fasteners using SAE J429 mechanical properties. The calculator accepts user inputs for thread type, thread size, bolt grade, friction coefficients, torque tolerances, and applied torque. The resulting preload envelope and safety ratios are computed automatically.

2. Usage Instructions

The module uses a two-panel interface. The left panel contains all inputs; the right panel displays calculated results.

• Select a Thread Type (UNC or UNF).

• Select a Thread Size (e.g., 1/4-20 UNC).

• Select an SAE Grade (1, 2, 4, 5, 7, or 8).

• Set torque tolerance values (+/– %). These expand the preload range.

• Enter minimum and maximum friction coefficients for:

  – Thread friction μ_thread

  – Head friction μ_bearing

• Enter the Specified Torque in in-lb. The module instantly updates results.

Safety indicator colors:
• Preload / Proof Load > 1 → yellow warning
• Preload / Min Tensile Load > 1 → red warning

3. Computational Methodology

The module follows established torque–tension and bolt mechanics relationships.

Key steps include:

1. **Thread Geometry:**
   Tensile stress area A_t is calculated using the Unified Thread formula:
   $A_t = 0.7854 \cdot (d - 0.9743/TPI)^2$

2. **Material Strength:**
   Proof, yield, and tensile strengths are taken from SAE J429 tables.
   Strengths vary by diameter for Grade 2 and Grade 5 bolts.

3. **Torque–Tension Relationship:**
   Detailed preload estimation uses frictional and geometric torque losses:
   $T = T_{thread} + T_{bearing}$
   where thread torque and bearing torque include μ, lead angle, and pitch diameter.

4. **Preload Envelope:**
   Minimum preload is computed using:
   – Lowest torque (minus tolerance)
   – Highest friction values
   Maximum preload uses:
   – Highest torque (plus tolerance)
   – Lowest friction values

5. **Safety Ratios:**
   Preload / Proof Load and Preload / Tensile Capacity are computed to assess risk.
   Values > 1 are flagged as exceeding material capacity.

6. **Nut Factor (K):**
   A simplified empirical nut factor is computed using averaged friction values. This is provided for compatibility with traditional torque–tension formulas such as $T = K \cdot F \cdot d$.

4. References

• SAE J429 — Mechanical and Material Requirements for Externally Threaded Fasteners.

• ASME B1.1 — Unified Inch Screw Threads.

• Machinery's Handbook — Bolt Torque, Preload, and Friction Models.

• Shigley, Mischke, Budynas: Mechanical Engineering Design — Chapters on Fasteners.

• NASA TM 106943 — Fastener Torque–Tension Testing and Variability.