

Metric Bolt Torque / Preload Calculator

1. Overview

The Metric Bolt Torque / Preload Calculator estimates preload, proof load utilization, tensile load utilization, and nut factor for ISO metric coarse threaded fasteners. The module accepts thread size, property class, friction coefficients, and applied torque, then computes the resulting preload envelope and safety ratios using standard ISO 898-1 mechanical properties and ISO metric thread geometry.

2. Usage Instructions

The interface is split into two side-by-side panels: an Inputs panel on the left and a Results panel on the right. Calculations are performed automatically whenever an input value is changed.

- Select the metric thread size (e.g., M8 × 1.25) from the Thread Size list. All sizes are standard ISO coarse pitch values.
- Select the Property Class (4.6, 5.8, 8.8, 10.9, or 12.9). These correspond to mechanical property classes defined in ISO 898-1.
- Enter the positive and negative torque tolerances as percentages. These represent variation around the nominal applied torque.
- Enter minimum and maximum thread friction coefficients (μ_{thread}) and head/bearing friction coefficients (μ_{bearing}). These define the friction range used to compute minimum and maximum preload.
- Enter the specified torque in N·m. The module converts this value to N·mm internally.
- Review the Results panel to see diameter, pitch, tensile stress area, proof/yield/tensile stresses, corresponding loads, preload range, safety ratios, and nut factor.

Visual indicators are used for key safety ratios:

- Preload / Proof Load > 1.0 → the field is highlighted yellow.
- Preload / Minimum Tensile Load > 1.0 → the field is highlighted red.

When the ratios are ≤ 1.0 , the fields remain gray (read-only background), indicating that the preload is at or below the corresponding capacity.

3. Computational Methodology

The calculator is based on widely used fastener design relationships.

1. 3.1 Thread Geometry and Tensile Area

The module assumes standard ISO metric coarse pitch single-start threads. For each selected nominal diameter d (mm) and pitch P (mm), the tensile stress area A_s is

approximated using the ISO metric tensile area formula:

$$A_s = 0.7854 \cdot (d - 0.9382 \cdot P)^2$$

where A_s is in mm^2 , d is the nominal major diameter, and P is the pitch.

2. 3.2 Material Strength Properties

For each property class, the calculator uses typical proof, yield, and ultimate tensile strengths taken from ISO 898-1 tables or commonly cited design values. These strengths are expressed in MPa (N/mm^2). The values are applied uniformly across all diameters for a given property class in this implementation.

3. 3.3 Load Capacity Calculations

Proof load, yield load, and tensile load are computed directly from the corresponding stress multiplied by the tensile stress area:

$$F_{\text{proof}} = \sigma_{\text{proof}} \cdot A_s$$

$$F_{\text{yield}} = \sigma_{\text{yield}} \cdot A_s$$

$$F_{\text{tensile}} = \sigma_{\text{tensile}} \cdot A_s$$

where σ_{proof} , σ_{yield} , and σ_{tensile} are in MPa, and A_s is in mm^2 . The resulting loads are expressed in Newtons (N).

4. 3.4 Torque–Tension Relationship and Friction

The applied torque is specified in $\text{N}\cdot\text{m}$ and converted to $\text{N}\cdot\text{mm}$ internally. A more detailed torque–tension relationship is used instead of a single empirical nut factor. The total torque is split into thread torque and bearing torque, each dependent on friction and geometry. An approximate thread pitch diameter D_m and lead (equal to pitch for single-start threads) are used along with a secant of the thread flank angle to model torque losses due to friction in the threads and under the head or nut.

Minimum and maximum preload are computed using the extremes of torque and friction:

- Maximum preload uses the maximum torque (nominal + tolerance) and minimum friction.
- Minimum preload uses the minimum torque (nominal – tolerance) and maximum friction.

This produces a preload envelope representing realistic assembly variation.

5. 3.5 Safety Ratios

Two key dimensionless ratios are computed using the maximum preload F_{max} :

$$R_{\text{proof}} = F_{\text{max}} / F_{\text{proof}}$$

$$R_{\text{tensile}} = F_{\text{max}} / F_{\text{tensile}}$$

When $R_{\text{proof}} > 1.0$, the preload exceeds proof load, and the result is highlighted yellow. When $R_{\text{tensile}} > 1.0$, the preload exceeds minimum tensile capacity, and the result is highlighted red. Values less than or equal to 1.0 indicate that the preload is within the respective capacity.

6. 3.6 Nut Factor (K)

For convenience, an equivalent nut factor K is computed based on the detailed model. Average thread and bearing friction coefficients are used to back-calculate a K value compatible with the simplified torque-tension formula:

$$T = K \cdot F \cdot d$$

where T is torque, F is preload, and d is nominal diameter. This allows designers to relate the detailed frictional model to traditional empirical K-factor methods.

4. References

- ISO 898-1: Mechanical properties of fasteners made of carbon steel and alloy steel — Part 1: Bolts, screws and studs with specified property classes.
- ISO 965 / ISO 261: General purpose metric screw threads — Basic and coarse pitch series.
- VDI 2230: Systematic calculation of high duty bolted joints.
- Shigley, Mischke, Budynas — Mechanical Engineering Design, chapters on threaded fasteners.
- Machinery's Handbook — sections on metric screw threads and bolt preload.