Intro to Preloaded Bolted Joint Design

Preloaded Bolted Joint Analysis – Lesson 1

Ansys

Bolted Joints

Bolted joints are a form of threaded fasteners.

- They’re used to hold assemblies together and for transferring forces from one component to another.
- They act as critical structural components in engineering assemblies.
- Although a physically small part of an assembly, they must be selected carefully.

Bolts Versus Screws

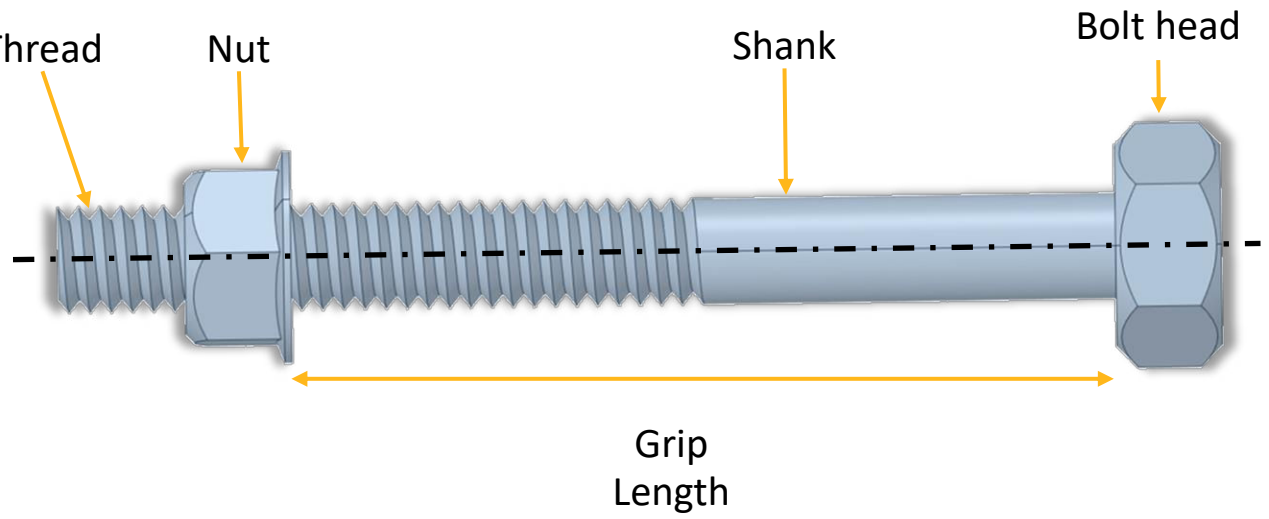
While bolts and screws are both types of threaded fasteners, they differ in significant ways.

- Bolts are generally accompanied by nuts that have threaded portions.
  - Connected components are generally sandwiched between the nut and the bolt.
- Screws engage with threads that are machined into an assembly component or in some cases, they cut their own threads in the component during installation.

Nomenclature

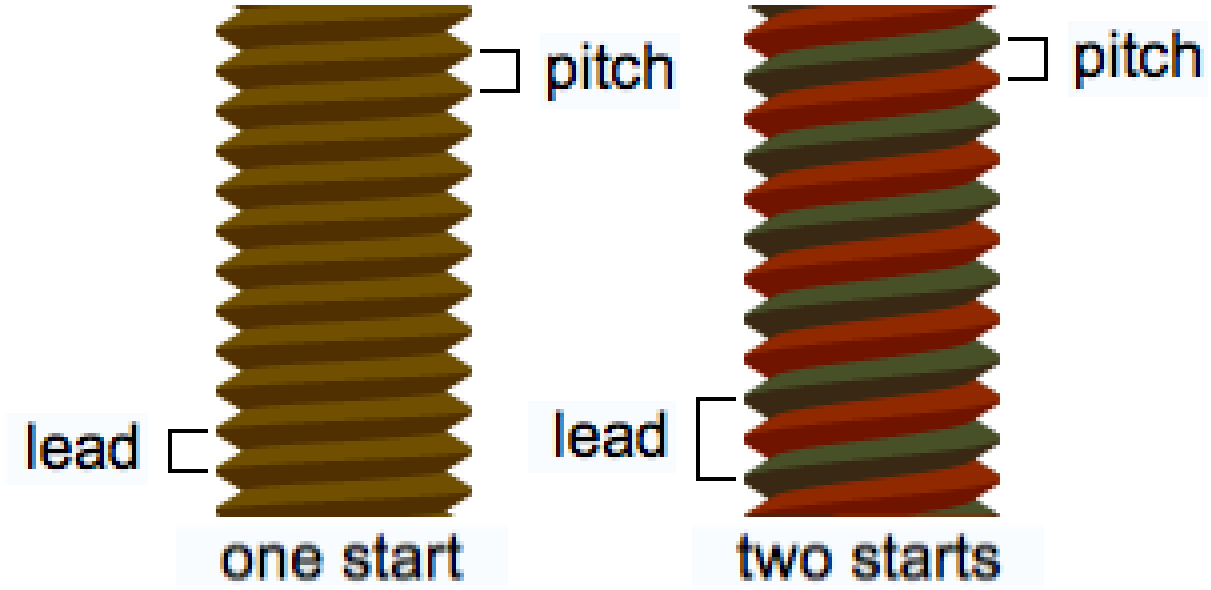
A bolt–nut assembly consists of several sections that play a role in the transfer of forces.

- Forces are transferred between the nut and bolt at the threads.
- The threadless portion of the bolt is called a shank.
- The portion of the bolt between the nut and the bolt head is known as the grip length.



Threaded Fasteners

- **Lead:** distance along the axis of a bolt covered in a single, full rotation
- **Pitch:** distance between the crests of two adjacent threads
- **Number of leads:** number of “ridges” wrapped around the bolt



Threaded Fasteners

In the design of bolted joints, the threaded fasteners are usually selected from existing options and not designed from scratch.

- Standard ways of representing bolts utilize the metric or inch systems.
  - In the metric system, the major diameter of the bolt is represented in millimeters (mm), followed by the pitch distance and length of the bolt also in millimeters (e.g., M8-1.25x30).
  - In the inch system, the major diameter is represented in inches followed by the number of threads per inch (= 1/pitch distance). For bolts whose major diameter is less than a quarter of an inch the diameter is indicated by an integer defined as a standard. For example, bolt #6-32 has a major diameter of 0.13 in and 32 threads per inch.
- In both the cases, the fasteners have "V" shaped threads with an angle of 60° between the threads.

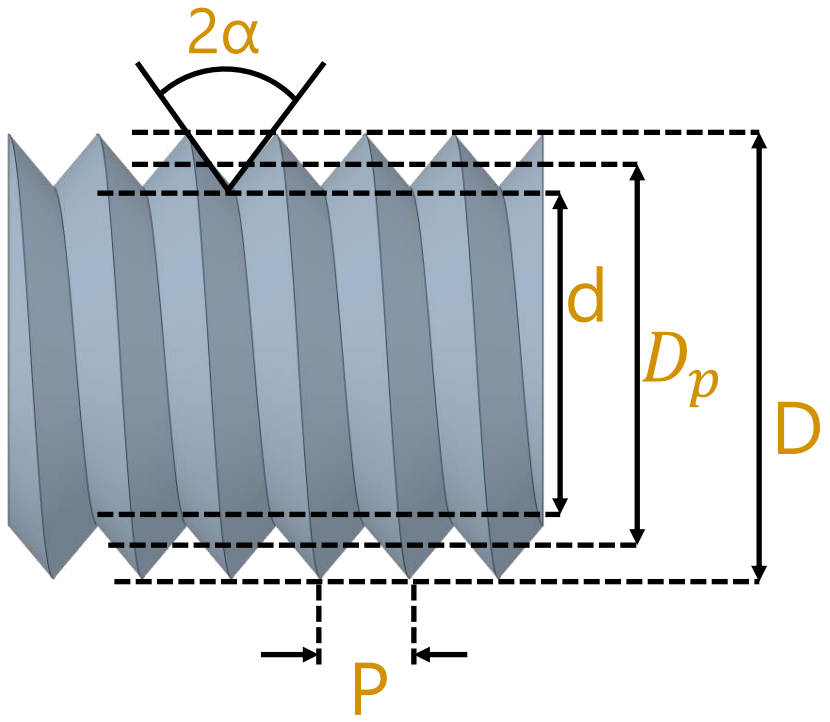
Threaded Fasteners

Terms related to thread dimensions:

- 2α → thread angle
- d → minor diameter
- D → major diameter
- P → pitch

- Another term that's commonly used is the pitch diameter, D_p:
  - It's typically halfway between the inner and outer diameters.
  - If only the major diameter is known, it may be approximated as:

$$D_p = D - 0.65P$$

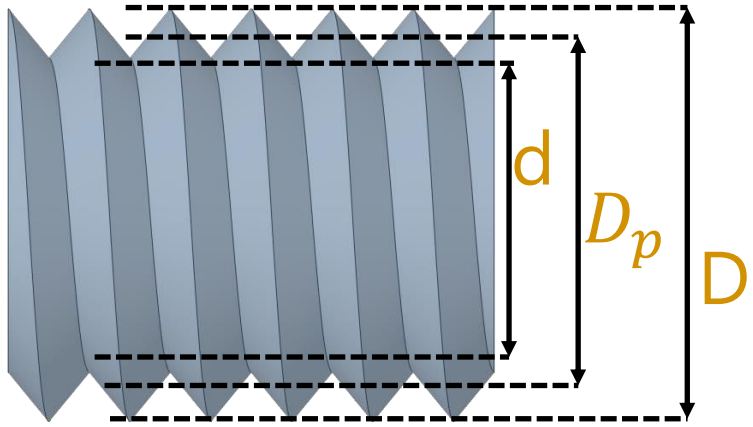


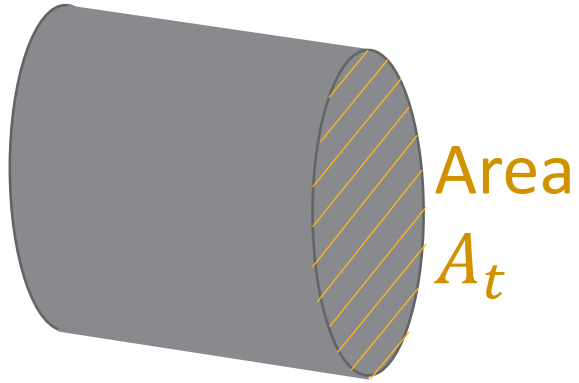
Threaded Fasteners

- Tensile-stress area, A_t, is another important parameter for a bolt.

$$A_t = \frac{\pi}{4}\left(\frac{\mathrm{d} + D_p}{2}\right)^2$$

- Tensile tests of threaded rods have shown that an unthreaded rod whose cross-sectional area is equal to the tensile-stress area A_t of the threaded rod has the same tensile strength as the threaded rod.
- When simplifying the geometry of a threaded bolt in a simulation and using a cylindrical bolt shank to represent its threaded portion, the area of the cylindrical portion should be equal to A_t of the bolt.

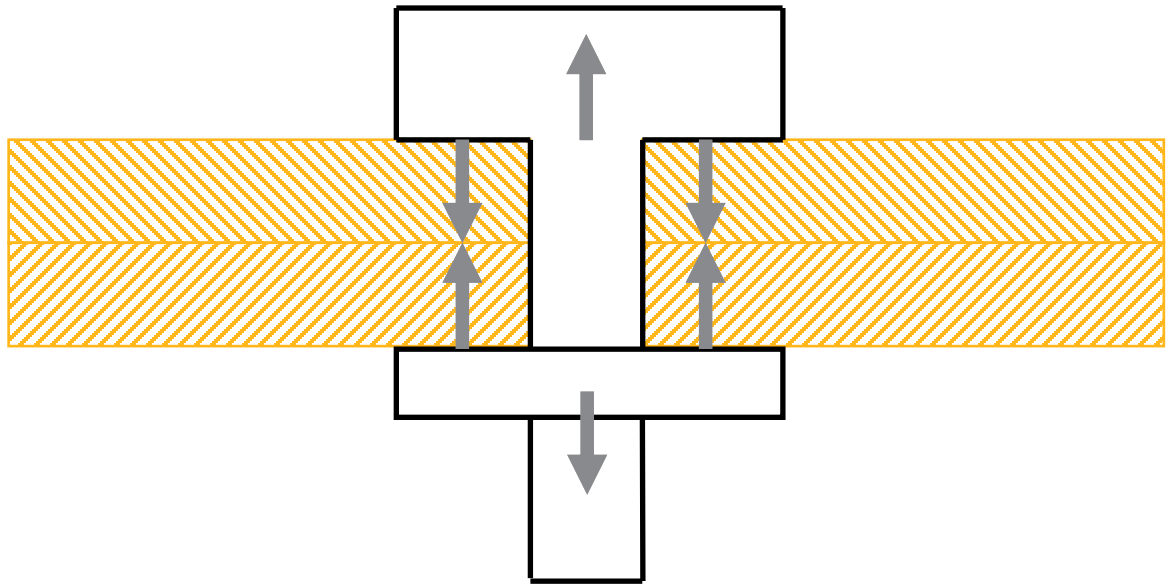




Typical Bolted Joint

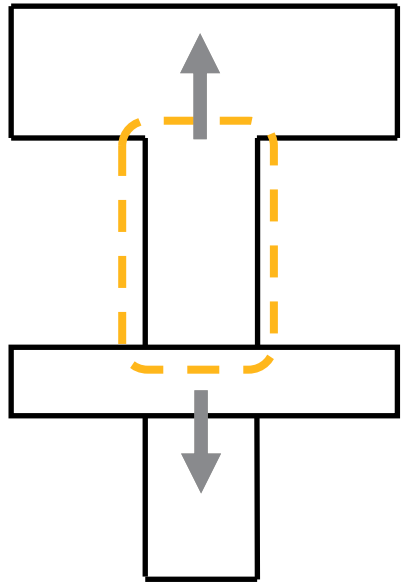
A typical bolted joint consists of two plates sandwiched between a nut and a bolt.

- When tightened, the nut and the bolt apply compressive forces on the two plates as they're pressed together.
- The reaction forces acting on the nut and the bolt head create a tension state in the shank.



Typical Bolted Joint (continued)

- Reaction forces create a state of tension in the shank.
  - As a result, a preload is present in the bolt when the nut is tightened.
  - This load is tensile in nature, and known as bolt preload, bolt pretension or clamp load.
  - To avoid failure of bolted joints and the bolt themselves, we need to calculate the appropriate value of the bolt preload to be applied to the bolt.



Calculating the Bolt Preload

- Bolted joints are designed based upon the proof strength and the corresponding proof load of the bolt.
- Proof strengths for good quality bolt materials are published in various design books. In the absence of published data, we can use:

$$\text{Proof strength} = 0.85 \times \text{Yield strength}^{1}$$

- Calculate the bolt proof load:

$$\text{Proof load} = \text{Proof strength} \times A_t{}^{1}$$

Proof load is the maximum load that a bolt can withstand without acquiring a permanent set.

- Calculate bolt preload:

$$\text{Preload} = 75 \text{ to } 90\% \text{ of Proof load}^{1}$$

[1]Budynas, Richard Gordon, and J. Keith Nisbett. *Shigley's Mechanical Engineering Design*. Vol. 9. New York: McGraw-Hill, 2011.

Failure of Bolted Joints

Bolt failure leads to structural failure.

- There are several reasons why bolted joints fail; the majority are related to the bolt load.
- Five main reasons:
  - Insufficient clamp force – joint does not support shear loads
  - Excess clamp load – clamp load is close to or exceeds proof load, and the bolt fails in tension
  - Shear failure – clamp fails in shear under shear loads
  - Fatigue failure – bolt subjected to cyclic tension loads; insufficiently tightened bolts accelerate fatigue
  - Thread stripping – too much friction and adhesion between mating threads can shear off the load-bearing threads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