Threaded Fasteners

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Screws are specified by five parameters:

1. Screw type: there are thousands of types of screw, varying in shape of head, type of driver, purpose (machine/wood/sheet metal), type of thread, and special characteristics (for example ported screws used in vacuum chambers). We will use socket-head cap screws, since they enforce use of the correct size driver and can withstand aggressive tightening.

2. Screw material: screws are available in many types of plastic and metal, with galvanized steel being the most common (primarily because of its high strength-to-cost ratio and moderate corrosion resistance). We will use type 304 (also known as 18-8) stainless steel screws, which have good corrosion resistance, are not unreasonably expensive (especially for a prototype or one-off instrument), and are readily available, for example at McMaster-Carr.

3. Major thread diameter: the major thread diameter of a screw is the outermost diameter of the threads. The actual major diameter is usually slightly smaller than the specified value.

4. Thread pitch: the thread pitch is the distance between subsequent crests (or roots) of the thread.

5. Length: the length of a screw is measured from the bottom of the head to the end of the screw, except if the screw has a flat head, in which case the length is measured from the top of the head to the opposite end. The actual screw length is usually slightly smaller than the specified value.

- Metric screws are specified by diameter, pitch, and length, all in millimeters. For example, a M8×1.25 80 mm screw has a major diameter of 8 mm, a 1.25 mm thread pitch, and is 80 mm long.

- Inch screws with major diameter less than or equal to 0.216″ are specified by a screw number, the number of threads per inch, and the length in inches. For example, your design might call for a #8-32×1/2 screw. The major diameter $D = 0.060 + 0.013N$, where N is the screw number, and D is in

inches. The above-mentioned #8-32 screw would have a major diameter of $0.164''$. For inch screws larger than #12 ($D = 0.216''$), the major diameter is specified in fractional inches. For example, one of the most common inch screw sizes is 1/4-20, with $0.25''$ major diameter and 20 threads per inch.

- To identify the thread on an undetermined screw, use a screw pitch gage and calipers, or match the threads with a known screw.
- Clearance holes are drilled large enough for a screw to pass unimpeded.
- A counterbore is a widening of one end of a clearance hole that enables the screw head to sit flush with or below the surface. The depth of a counterbore must usually be greater than or equal to the screw's major diameter.
- Tap holes are drilled smaller than the major diameter of the screw so that they can subsequently be threaded using a tap. The diameter of a tap hole is typically found by subtracting the screw's pitch from its major diameter.
- Screw strength is determined by the screw's minimum cross-sectional area and the yield stress of the material. For a 1/4-20 304 stainless steel screw, the yield stress $\sigma_y \approx 2 \times 10^8$ Pa. The nominal major diameter $D = 0.25''$ $= 6.35$ mm. The pitch $p = 0.05'' = 1.27$ mm. For 60° threads, the minor diameter $d \approx D - 2p\cos 30^\circ = 4.15$ mm. The cross sectional area is then $A = \pi(d/2)^2 = 13.5$ mm^2. For the screw material to deform permanently requires a force $F = \sigma_y A = 2 \times 10^8$ Pa $\times\, 1.35 \times 10^{-5}$ m^2 $= 2700$ N $= 608$ lb. The ultimate tensile stress for 304 stainless steel is about 5×10^8 Pa.
- Holes are generally tapped to a depth (1.5 major diameters to be safe) such that if a very large load is applied, the screw will break before the tapped hole is damaged.
- Everything else you need to know about screws can probably be found in Machinery's Handbook.