EML2322L – Design & Manufacturing Laboratory

Fastener Facts

1. **Definitions.** The term *fasteners* refers to hardware that can be easily installed and removed with hand or power tools. Common fasteners include screws, bolts, nuts, and rivets. The term *bolt* refers to a male fastener that requires a nut to function, whereas the term *screw* refers to a male fastener that is mated into a matching female thread in a workpiece. A bolted assembly requires two tools to tighten or loosen, whereas a screwed assembly only requires one (the part with the female threads is typically stationary).

2. **Common fastener types.** The most common male fastener types used in industry are hex head, slotted head, flat (or countersunk) head, round head, socket (or allen) head, button head and socket set screw. The most common nuts are regular hexagonal nuts and nylon ring elastic stop nuts (aka lock nuts).

3. **Fastener nomenclature.** Be familiar with the following parts of a male fastener: *head, bearing surface, shank, grip length, total length, thread length, thread pitch, thread crest, thread root and point.*

4. **Fastener and thread types.** There are two general classes of fastener threads: English and metric. For each class there are two types of threads: fine and coarse. (Refer to the tap chart, as it summarizes all of this information.) Fine threads are stronger when the nut material is strong relative to the bolt material and coarse threads are stronger when the nut material is weak relative to the bolt material. **Refer to the lecture notes for the justification of this important statement.**

5. **Rolled threads.** Quality fasteners have rolled threads produced via rolling or sliding dies as seen here. Rolled threads, as opposed to threads cut on a lathe or with a *cutting die,* produce superior surface finish (thus lower stress risers) and improved material properties (grain flow) from cold working the material, resulting in higher fatigue resistance; they are also more economical to manufacture in larger quantities.

6. **Fastener function.** **Fasteners have only ONE intended function: to clamp parts together.** Fasteners are not meant to position parts relative to one another; that is the function of dowel pins, locating shoulders, and piloting diameters. Fasteners are not meant to function as pivots, axles and fulcrums; again, pins appropriately serve this function. *(Note: students often get away with using fasteners to locate parts on their designs in this course because of the light duty, short-term use of the project and convenience of doing so; in use these bolted connections will loosen, causing the assembly to fail. This problem is avoided by regularly checking for loose fasteners prior to testing, which will not occur once your design is mass produced and released into the hands of consumers.)*

   More importantly, the threaded portion of a fastener should NEVER be loaded in shear for three reasons. First, the threaded portion of the fastener is of slightly smaller diameter than the unthreaded shank, making the thread a looser fit in any hole it passes through; this will allow the fastener to more quickly loosen as transverse (i.e. shear) loading is applied. Second, the threaded portion of the bolt has much less surface area than the unthreaded shank, which means it also offers significantly less bearing area to the joint; this reduces both the load carrying capacity and fatigue resistance of the assembly. Third, when (not if!) the relative motion between the hole and the loose fitting threaded portion of the bolt occurs, the thread will act as a low speed file, removing material from the inside of the hole, worsening the problem. **In conclusion, competent design engineers NEVER load fastener threads in shear.**

Copyright Notice: much of this content was sourced from Carroll Smith's excellent *Nuts, Bolts, Fasteners, and Plumbing Handbook.*

7. **Over-tightening vs. under-tightening.** The following is an example from Carroll Smith's Nuts, Bolts, Fasteners and Plumbing Handbook (and is included in the lecture notes.) A 3/8″ diameter bolt with an ultimate tensile strength (UTS) of 180,000 psi was torqued to 40% of its UTS (72,000 psi) and subjected to a cyclic tension load of 12,000 lb_f. The bolt endured 4,900 force application cycles before failure. An identical bolt was torqued to 60% of its UTS (108,000 psi) and subjected to THE SAME cyclic tension load of 12,000 lb_f. This bolt endured 6,000,000 cycles before failure, or **roughly 1000 TIMES more stress cycles (or service life).** **This example demonstrates the necessity for engineers to specify the correct installation torques of all fasteners used in critical assemblies.**

8. **Calculating proper fastener torque.** The lecture notes contain a good example of how to calculate the tightening torque for different size and strength fasteners; this is one of the most valuable pieces of information you can take away from this course, so please review it carefully. The example presents a simple equation that relates desired fastener preload to the installed (or measured) fastener torque:

   $$T \approx 0.2 \times F_i \times d$$

   where T is the measured installation torque (measured with a torque wrench)
   F_i is the desired preload (installed tensile force in the bolt)
   d is the nominal bolt (shank) diameter

   This simplified equation results in approximately 80% accuracy, which is within the tolerance of most fastener specifications we need to provide. As shown in the detailed example in the notes, the desired installed tensile stress of a grade 5, 3/8″-16 bolt is approximately 76,500 lb_f. Based on the cross sectional thread geometry of this fastener, this results in F_i = 5,929 lb_f. Using this value and the fastener diameter in the above equation, we can calculate the desired (or specified) torque is equal to **37 lb-ft.**

9. **Fastener choices.** The only fastener choices available off the shelf (OTS) are the ones listed on the tap chart. **These are THE ONLY options available to us when selecting fasteners and designing parts, as anything else would require prohibitively expensive custom tooling and fasteners.** So ALWAYS reference the tap chart when selecting fasteners.

10. **Fastener designations.** In general, fasteners are referred to by their shank size (i.e. a ½″ or a 12mm fastener). Standard (inch) fasteners are referred to by their shank size and the number of threads per inch they possess (i.e. 3/8″-16 or ½″-20), and are pronounced "three-eighths sixteen" or "one-half twenty." Standard (inch) fasteners which are ¼″ and larger are referred to by their nominal shank size. Fasteners smaller than ¼″ are referred to by a screw size designation, such as "number 10" or "number 6". Metric fasteners are referred to by their shank size and thread pitch (i.e. M6x1.0 or M10x1.5), and are pronounced "metric six by one" or "M ten by one point five".

11. **Tap drill.** *Tap drill* refers to the **final drill size** used to make a properly sized hole prior to using a tap (internal threading tool) to cut threads into the hole. The size of this hole is critical and must be obtained from a tap chart like the one provided in this course or found in the Machinery Handbook. **If this hole size is too small the tap will break when trying to create the threads; if the hole size is too large, the threads will be weak and fail in service.** Note the tap drill size listed on the tap chart for a particular thread depends on the material type (weaker or stronger).

12. **Clearance drill/hole.** *Clearance drills* are used to create exactly what the name implies: *clearance holes* for fasteners, shafts, or pins. Industry standards for clearance holes are listed in the last column of the tap chart. Note there are only two options for each size fastener: close fit or free fit. Close fit clearance holes are used when you want a more accurate bolt pattern (e.g. when using the DRO on the milling machine) and free fit clearance holes are used when you want to save time and make the clearance holes more quickly (e.g. when using a drill press or hand drill). **Clearance hole sizes listed on the tap chart are industry standards and should always be used unless you have a very good reason to deviate.**

Copyright Notice: much of this content was sourced from Carroll Smith's excellent *Nuts, Bolts, Fasteners, and Plumbing Handbook.*