Basic Fastener Theory

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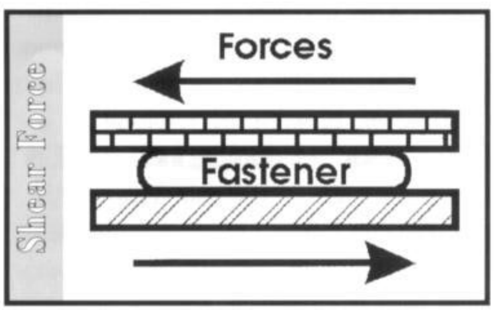
No matter what fastener is used in a given application, all fasteners perform generally the same purpose. Quite simply, fasteners join two or more pieces of material. Some fasteners fasten the same type of materials and others can be used on a variety of materials.

Just as all fasteners have the same general purpose, they all face the same general concerns. In choosing the most appropriate for a given application, several things must be taken into account, such as economics and availability, plus strength and durability (an ASME Nuclear Grade bolt is extremely strong, but it will cost you one leg and both arms). This section focuses on the various loads the fasteners must undergo.

Various Loads to Bear

Shear Forces. Shear forces are the forces that act against the direction of the fastener.

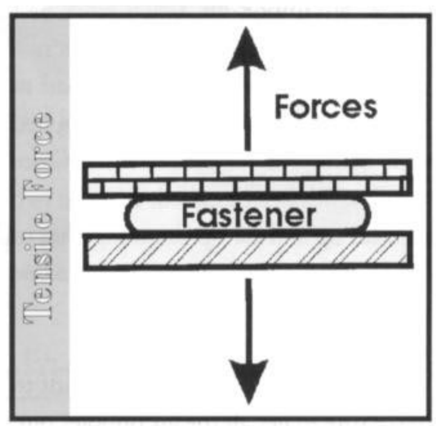
Shear forces tend to rip a fastener against the grain, and there is usually



very little deformation of the fasteners. Another problem that exists is that once shear deformation begins, there is little or no recover within the material. In other words, once deformation begins, the material does not bound back into its original material.

Tensile/Compressive Forces. Tensile and compressive forces are the forces that act in the direction of the fastener. Tensile forces pull on the fastener and stretch it out while compressive forces tend to squeeze the fastener. In most cases, compressive forces are not a big problem in most application. Tensile loads, however, tend to stretch the fastener and can lead to failure of the part in extreme cases. The most probable problem with tensile stresses occurs when the fastener is elongated and looseness can quickly occur.

Tensile and shear stresses (force divided by cross-sectional area) are present in almost all applications. While it may not be possible to calculate the exact force, rough estimates can be made using certain techniques. Once an estimation of the forces and the stresses is obtained, one can determine if the product will be likely to fail. Some suppliers provide information on the maximum safe loads their products can support, but if this information cannot



be obtained, material property tables give the values for a variety of materials.

While these calculations are only an estimate, they will tell you whether or not a component of your project is questionable or might fail. Its always better to be safe than sorry, so be sure your fasteners can support the loads they are expected to handle.

Basic Adhesives Theory

This section presents the basic theory necessary to use adhesives effectively. The treatment in this section is primarily on an elementary level; consult an expert or the product manufacturer for complex analyses or calculations.

Preparation. Before any adhesive can be applied, there are a few steps to follow to minimize problems.

The instructions on the adhesive should be read carefully. Old clothes should be worn, and tarps, old sheets or newspaper should be used to cover area. Make sure that the surfaces for the adhesive to be applied to are clean and dry. If applying adhesive to surfaces such as metal or glass, rough the surfaces to help in the adhesive process; this can be done by sanding.

Application. Application of the adhesive is very important. Glues work best when a thin layer is applied to both surfaces. Too much glue is just as bad as too little glue. The glue can be applied with brushes or Popsicle sticks. Once the glue has been applied, line the two surfaces up and clamp them together to dry. Be sure to wipe away any excess glue before it dries.

When applying tape, it is important to make sure to get all the air bubbles out.

Curing Time and Cleanup. Different adhesives require different curing times. It is important to read and follow the directions that pertain to each adhesive. The materials should be dried at room temperature, in a dry environment and out of direct sunlight.

Cleanup should be done as you go. Most cleaners will not remove adhesives after drying. Make sure to properly close all adhesive containers, and store them out of the reach of children in a dry place at room temperature.

Threaded Fasteners

How do bolted joints work? Bolted joints use the bolt to “squeeze” the parts together, which should be fairly apparent. What may not be apparent is that a properly assembled bolted joint actually stretches the bolt as it clamps the members between it, resulting in a compressive stress in the members and a tensile stress in the bolt. This load is called the bolt pre-load, and is desirable. When an external load tries to separate the members, a tensile stress is exerted on the members and on the bolt-the bolt takes some of the load, and the members take the rest. The pre-load, however, means that any tensile load on them must first overcome the compressive stress in the members before it can begin to try to separate the members from each other. Bolted joints are normally designed so that the maximum load that is expected to be supported by the members is smaller than the pre-load, so that the members will never be separated in operation of the joint.

Types of Bolts

Bolts come in many different sizes and are available in both metric and English units. There are standard sizes for bolts, however, that standardize the dimensions on the different sizes of bolts so that they are known without actually buying the bolts themselves. These dimensions are tabulated in any mechanical engineering handbook. Information about the standard unified national fine and course thread series threads, which are widely used, are shown in the tables on page 23.

The meanings and uses of the values in the tables are defined as follows:

Size. The size of the bolt indicates the nominal diameter of the bolt. The size is normally the diameter of the unthreaded portion of the bolt but for small sizes, a size number designation is given so that sizes that are not standard fractions can be used.

Nominal Diameter The diameter of the bolt. This information is only necessary for the smaller bolts, since the size column is the same as the diameter column for bolts 1/4 inch and larger.

Threads Per Inch. This is the pitch, or the number of threads per inch of threads on the bolt. This figure is important when calculating how many turns of the nut on the fastener will be required to clamp the members, or how much of the thread will extend beyond the nut when clamped. The inch is also very important when using standard threads for power screw applications, because it defines how many turns will be required to move the nut a given distance along the thread.

Tensile Stress Area. The tensile stress area (in square inches) is the cross-sectional area that should be used when calculating the stress on a bolt that results from an applied load. The tensile stress area is generally calculated (as it is in the tables) by using the cross-sectional area corresponding to the average of the minor diameter and the pitch diameter.

Minor Diameter. The minor diameter of a bolt is the diameter of the valleys in the bolt's threaded region.

Bolt Strengths

Bolts have a variety of strengths because there is are a number of different materials from which they are made. Since bolts are normally holding other parts together, they are classified by proof strength instead of yield strength.

The proof strength of a bolt is the strength at which the bolt deforms permanently This strength usually corresponds to about 90 percent of the yield strength of the material the bolt is made from. For standard, low carbon steels, the proof strength of bolts from 1/4 to 1-1/2 inch in diameter is about 33 ksi. For medium carbon steels, you can count on a minimum proof strength of bolts of about 85 ksi for the same sizes, and for medium carbon, heat treated bolts you can get as high as about 120 ksi proof strength.

Using Washers

Whenever you use a bolted joint, whether you are using a screw or a bolt and nut, you should always use washers. Here are several reasons that you should use washers:

Bearing Stress. Using washers reduces the bearing stress on the member surfaces by distributing the load over the washer area instead of just the bolt head area. For materials like wood and other soft materials, this is critical because the bolt head or nut might start to sink into the member surface before an adequate pre-load is reached. Separation can occur, in addition to the damage of the member surface.

Vibration. Washers help prevent nuts and bolts from coming loose during operation of the joint, especially when vibration is present.

Tightening. Washers make it easier to tighten a bolt and nut joint by keeping them from turning when the other part is turned. This is especially important when it is difficult to get at one side or the other of the joint.

Strength. Although really only an issue when high-strength joints are being used, washers help prevent damage to the nut and bolt from any burs that might exist from drilling holes. Burrs on the surface can cause failure when high stresses are imposed on the joint.

Unified National Course (UNC) Threads

Size	Major Diameter(in)	Threads/ inch	Tensile Stress Area (in^2)	Minor Diameter(in)	Thread Length(in)
1	0.0730	64	0.00263	0.00218	0.396
2	0.0860	56	0.00370	0.00310	0.422
3	0.0990	48	0.00487	0.00406	0.448
4	0.1120	40	0.00604	0.00496	0.474
5	0.1250	40	0.00796	0.00672	0.500
6	0.1380	32	0.00909	0.00745	0.526
8	0.1640	32	0.01400	0.01196	0.578
10	0.1900	24	0.01750	0.01450	0.630
12	0.2160	24	0.02420	0.02060	0.682
1/4	0.2500	20	0.03180	0.02690	0.750
5/16	0.3125	18	0.05240	0.04540	0.875
3/8	0.3750	16	0.07750	0.06780	1.000
7/16	0.4375	14	0.10630	0.09330	1.125
1/2	0.5000	13	0.14190	0.12570	1.250

Unified National Fine (UNF) Threads

Size	Major Diameter (in)	Threads/ inch	Tensile Stress Area (in^2)	Minor Diameter (in)	Thread Length(in)
1	0.0730	72	0.00278	0.00237	0.396
2	0.0860	64	0.00394	0.00339	0.422
3	0.0990	56	0.00523	0.00451	0.448
4	0.1120	48	0.00661	0.00566	0.474
5	0.1250	44	0.00880	0.00716	0.500
6	0.1380	40	0.01015	0.00874	0.526
8	0.1640	36	0.01474	0.01285	0.578
10	0.1900	32	0.02000	0.01750	0.630
12	0.2160	28	0.02580	0.02260	0.682
1/4	0.2500	28	0.03640	0.03260	0.750
5/16	0.3125	24	0.05800	0.05240	0.875
3/8	0.3750	24	0.08780	0.08090	1.000
7/16	0.4375	20	0.11870	0.10900	1.125
1/2	0.5000	20	0.15990	0.14860	1.250

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This material has been reprinted from the web site of the Systems Realization Laboratory in the G. W. Woodruff School of Mechanical Engineering, Georgia Institute of Technology, Atlanta. This material is available at www.srl.gatech.edu/DLS/primer. The main web site for the Systems Realization Laboratory is at www.srl.gatech.edu.

David Cowden, Jennifer B. Craine, Joseph Craine III, Artis Ray and Garig Vandervelt wrote or contributed substantially to the material in this article. It is part of the virtual Product Realization Studio, an online design/education environment developed by Farrokh Mistree, Janet K. Allen and David Rosen. The manager of the project is David D. Clark.

Cowden will graduate with a master's in mechanical engineering and plans to work in computer integrated manufacturing upon graduation.

Jennifer B. Craine, who will graduate from Georgia Tech next month as a mechanical engineer, was interviewing for employment as this issue of the magazine went to press.

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