

# Part 2 of 6:

# FASTENERS

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# 1 Definition

For our purposes, a fastener may be defined as any device, method or component used to hold or **FASTEN** two or more engineering components together.

Fasteners may be classified into groups and sub-groups according to the functions they perform. Probably the main division is into:

- (a) **detachable fasteners** (e.g. nut and bolt, screw, etc.);
- (b) **non-detachable fasteners** (e.g. rivet, weld, adhesive).

However, they can also be classified according to whether they:

- (i) **locate and clamp together two or more components**, e.g. the wheels on a car are each held onto the wheel hub by a number of nuts. These nuts are tightened securely to **clamp** the wheel to its hub to prevent movement;
- (ii) **locate only**, e.g. on children's toys the wheels are located or retained on the axles but the fasteners are such that they allow the wheels to rotate freely on the axle.

## 2 Detachable Fasteners

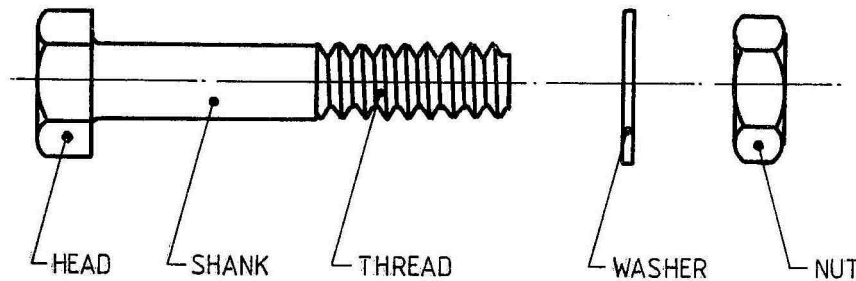
### 2.1 Threaded fasteners

Of the available fasteners, the most widely and generally used group is **THREADED FASTENERS**. This group includes bolts and nuts, set screws and screws. They are almost invariably intended to be detachable fasteners and are often used to provide both location and clamping, but can be used to locate only.

#### 2.1.1 Bolts and nuts

The components of a typical threaded fastener, in this case a hexagon-head bolt, flat washer and nut, are shown in Fig. 2-1. Some of the terms associated with a threaded fastener are shown in Fig. 2-2. The **THREAD** is a helical groove which in

some processes is cut (machined) into the major diameter of the bolt <sup>1</sup>. The helix is normally right-hand. A few bolts made for special purposes may have a left-hand helix, or left-hand thread (refer to Fig 2-15). The threads on the bolt are called **EXTERNAL** threads.



**Figure 2-1:** A hexagonal bolt, a flat washer and a hexagonal nut.

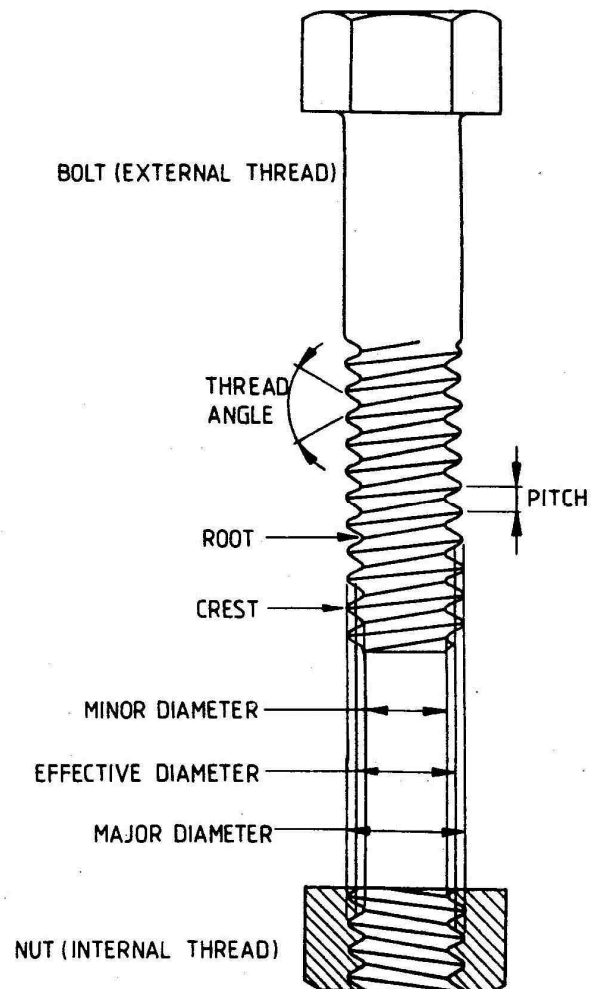
Reproduced from *Mechanical Technology 1*, NSW Dept. of Technical and Further Education.

Fig 2-2 introduces some bolt and thread terminology, most of which is self explanatory. The **PITCH** of the thread is the axial distance between adjacent crests of the helix. The definitions of **MAJOR DIAMETER**, minor **DIAMETER** and **EFFECTIVE DIAMETER** become important when calculating bolt strength.

Nuts must be made to screw onto the bolt and hence must have an **INTERNAL** thread to match the **EXTERNAL** thread on the bolt. The internal thread must be compatible in size (diameter), hand (left or right) and pitch of the helix if the nut is to screw freely and effectively onto the bolt. The nut in Fig 2-2 is a right-hand helix, although it appears to be a left-hand helix, because the nut is sectioned and the view shows the back half of the thread.

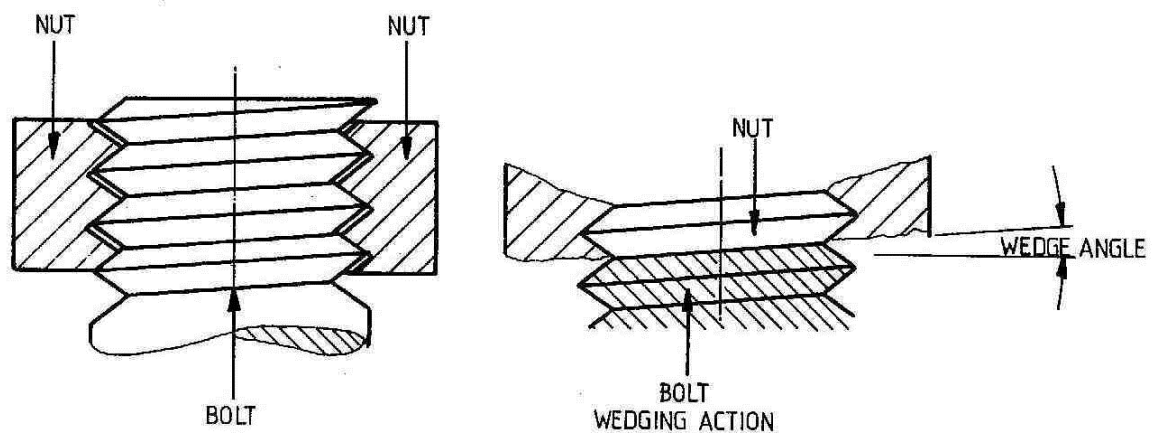
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<sup>1</sup> External threads are often mass produced by thread rolling, as described in Project 1, Fig 1-13, which displaces material from the “valleys” of the thread to form the “crests”.



**Figure 2-2:** Diagram of bolt and thread definitions.

Reproduced from *Mechanical Technology 1*, NSW Dept. of Technical and Further Education.



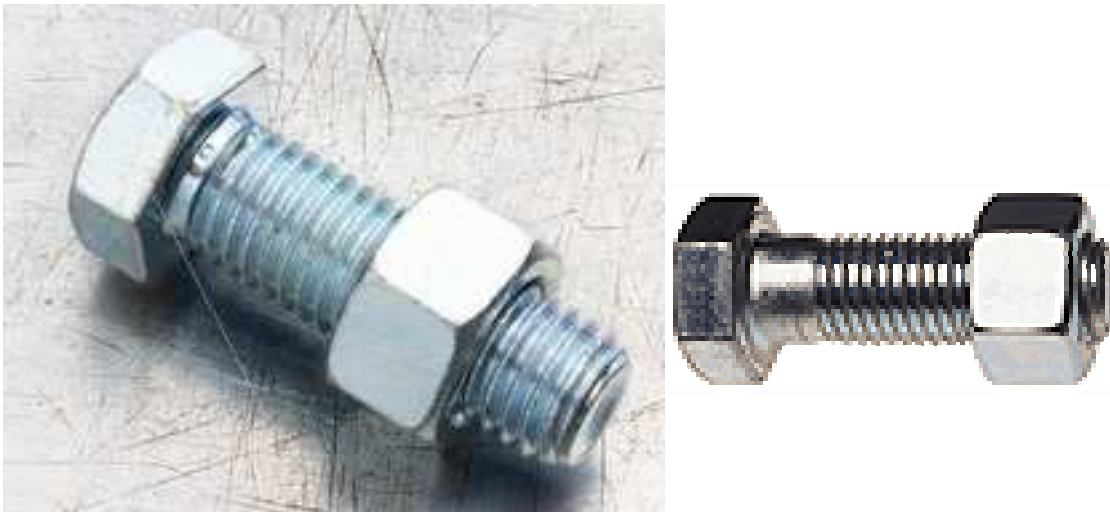
**Figure 2-3:** Close-up view of a nut and bolt being tightened, showing the clearance on the thread and the wedge angle.

Reproduced from *Mechanical Technology 1*, NSW Dept. of Technical and Further Education.

There will always be some clearance between the external and internal threads, as may be seen in the left-hand diagram in Fig. 2-3. As the nut is tightened, opposing axial loads are applied to the bolt and the nut, so all the thread clearance is on one flank of the thread.

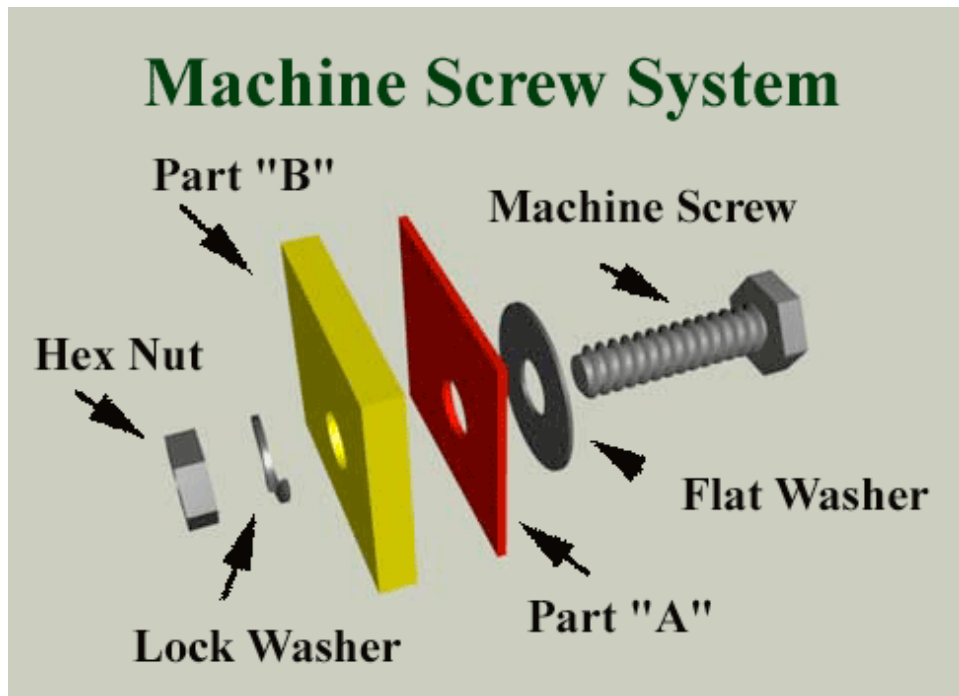
The helix angle of the thread is equivalent to a wedge angle. If the helix has a large angle, there will be a tendency for the tightened nut to “slide down the slope”, i.e. to loosen of its own accord when subjected to axial loading. The tendency to loosen increases if the fastener is used in a vibrating environment, e.g. in an engine, motor vehicle or aircraft. Conversely, threads with a small helix angle are less likely to self-loosen and might be thought of as tending towards “**SELF LOCKING**”.

Threads with larger helix angles are referred to as **COARSE THREADS**, those with small helix angles as **FINE THREADS**.



**Figure 2-4:** Commercially available hexagonal-head bolts with standard hexagonal nuts. The item on the left has a plated finish, probably zinc.

<http://www.boltsnutsscrewsonline.com/shop>



**Figure 2-5:** A schematic of two parts of a machine which are to be held together by means of a machine screw (or bolt) and nut. Depending on the hardness of the machine parts "A" and "B" and the need to prevent loosening, various arrangements of washers may be chosen, e.g.. small flat washer or no washer under the head, flat washer and/or spring washer and/or lock washer under the nut.

[http://www.gearseds.com/curriculum/images/figures/web\\_machine\\_screw\\_system.gif](http://www.gearseds.com/curriculum/images/figures/web_machine_screw_system.gif)

## 2.1.2 Other types of threaded fasteners

### 2.1.2.1 Bolts and setscrews



**Figure 2-6:** Top and side views of some of the range of bolts and screws which are commercially available.

Source not known.



**Figure 2-7:** A carriage bolt with cup head and square nut, often used (with a flat washer under the nut) in timber construction. The square section under the cup head may be driven into the drilled bolt hole in timber to prevent the bolt from turning when the nut is tightened. <http://en.wikipedia.org/wiki/Screw>



**Figure 2-8:** A square **U-BOLT** (*left*) which can be used with the matching plate shown. *Right:* Other U-bolt shapes, semi-round and round. U-bolts may be used to clamp together a number of components.

<http://www.google.com.au/search?client=safari&rls=en&q=U+bolts+pictures>

### 2.1.2.2 Studs



**Figure 2-9:** Examples of **STUDS**. These are lengths of rod or round bar, usually steel, with threaded lengths on each end and a length of unthreaded rod in the middle.

[http://www.allensfasteners.com/detail.asp?Product\\_ID=23008](http://www.allensfasteners.com/detail.asp?Product_ID=23008)

<http://www.nutsandbolts.com/> <http://www.te-co.com/Metric+Studs-C-PG1026-C-.aspx>

As may be seen in Fig 2-9, studs are cylindrical components with threads, similar to those on a bolt, on both ends of the cylinder. There is no head. There is usually a length of the central section of the cylinder which is not threaded.

Fig. 2-16 below shows a typical assembly using a stud. The stud is screwed in as far as possible to wedge the end of its thread into its tapped hole (it does **not** “bottom” in the hole), using a special tool which grips the unthreaded section. With all components in place, a nut is then screwed on to tighten the assembly. The stud is a semi-permanent fixture in the hole and it is usually possible to unscrew the nut, leaving the stud still in place.



### 2.1.2.3 *A word about screws and setscrews*

The terminology distinguishing bolts, setscrews and screws is not always clearly observed.

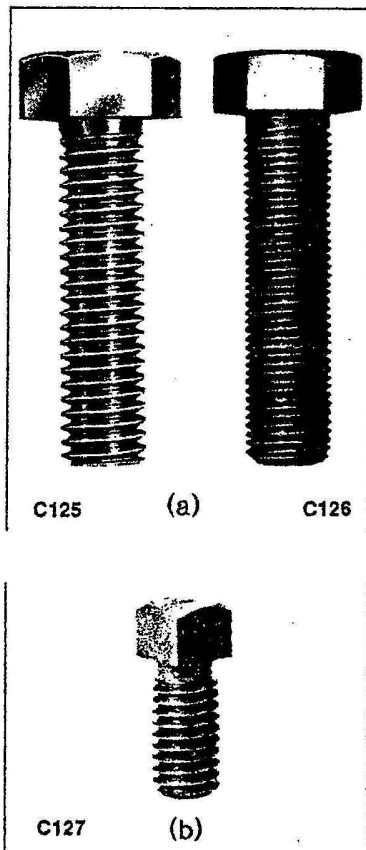
The component in Fig. 2-1 is clearly a **BOLT**. This particular item has a hexagonal head, but a bolt may have a head of other shape (cup, square, socket head, etc.).

According to one convention, the threaded section of the bolt extends over only portion of the cylindrical section, leaving an unthreaded **SHANK**, as in Fig 2-1. Had the thread been continued over the whole of the cylindrical portion, this would be classed as a **MACHINE SCREW** or **SETSCREW**. Figure 2-10 shows a coarse-thread and a fine thread hexagonal-head setscrew. Another convention restricts the definition of **SETSCREWS** to components similar to the square-head **CUP-POINT SETSCREW** shown at the bottom of Fig. 2-10. The special uses of setscrews such as the one in Fig 2-10 will be discussed later in these notes (Part 6 – *Power Transmission Elements*).

Setscrews, in the broader definition used in these notes, may have a variety of head shapes in addition to hexagonal. One frequently used head is round, with an internal hexagon; this is often referred to as a **SOCKET-HEAD CAPSCREW**. The capscREW is tightened by means of a tool of hexagonal cross-section called an **ALLEN KEY** fitted into the internal hexagon. Refer back to Fig 2-6 for illustrations of other setscrews or machine screws.

In other threaded components, the head is provided with a slot for a screwdriver or other driving tool; these are referred to as **SCREWS**. In screws, the thread usually continues over the whole of the cylindrical portion, right up to the head. The “screwdriver” recess may be either a single slot, the crossed slots of Phillips head or Posidrive, or an internal hexagon. Note that Phillips and Posidrive are similar but NOT identical and different tools are needed for the two systems.

The Australian Engineering Drawing Handbook (published by The Institution of Engineers, Australia), as well as various mechanical design textbooks (e.g Boundy) and commercial brochures provide more detailed information.

**Brass Set Screws continued**

The use of the cold process on a mass production basis now frees Brass Set Screws from the former disadvantage of high cost where corrosion must be considered.

Mechanical Properties: See Brass Bolts and Nuts.

**C125—BRIGHT STEEL HEXAGON SET SCREWS**

**B.S.W.**

Lengths:  $\frac{3}{4}$ , 1,  $1\frac{1}{4}$ ,  $1\frac{1}{2}$ ,  $1\frac{3}{4}$ , 2,  $2\frac{1}{2}$ , 3,  $3\frac{1}{2}$ , 4,  $4\frac{1}{2}$ , 5,  $5\frac{1}{2}$  in.

Dia.:  $\frac{1}{16}$ ,  $\frac{1}{4}$ ,  $\frac{5}{16}$ ,  $\frac{3}{8}$ ,  $\frac{7}{16}$ ,  $\frac{1}{2}$ ,  $\frac{5}{8}$ ,  $\frac{3}{4}$ ,  $\frac{7}{8}$ , 1 in.

**B.S.F.**

Lengths:  $\frac{3}{4}$ , 1,  $1\frac{1}{4}$ ,  $1\frac{1}{2}$ ,  $1\frac{3}{4}$ , 2,  $2\frac{1}{2}$ , 3 in.

Dia.:  $\frac{1}{16}$ ,  $\frac{1}{4}$ ,  $\frac{5}{16}$ ,  $\frac{3}{8}$ ,  $\frac{1}{2}$  in.

**UNF**

Lengths:  $\frac{3}{4}$ , 1,  $1\frac{1}{4}$ ,  $1\frac{1}{2}$ ,  $1\frac{3}{4}$ , 2,  $2\frac{1}{2}$ , 3 in.

Dia.:  $\frac{1}{16}$ ,  $\frac{1}{4}$ ,  $\frac{5}{16}$ ,  $\frac{3}{8}$ ,  $\frac{1}{2}$  in.

**UNC**

Lengths:  $\frac{3}{4}$ , 1,  $1\frac{1}{4}$ ,  $1\frac{1}{2}$ ,  $1\frac{3}{4}$ , 2,  $2\frac{1}{2}$ , 3 in.

Dia.:  $\frac{1}{16}$ ,  $\frac{1}{4}$ ,  $\frac{5}{16}$ ,  $\frac{3}{8}$ ,  $\frac{1}{2}$  in.

Larger sizes can be supplied against order.

**C126—BRASS OR STAINLESS STEEL MACHINED SET SCREWS**

Diameter:  $\frac{3}{16}$  to  $\frac{1}{2}$  in. Lengths:  $\frac{3}{4}$  to 2 in.

Larger sizes can be supplied against orders.

**C127—SQUARE HEAD CASE HARDENED CUP POINT SET SCREWS**

Diameters:  $\frac{1}{4}$ ,  $\frac{5}{16}$ ,  $\frac{3}{8}$ ,  $\frac{1}{2}$ ,  $\frac{5}{8}$ ,  $\frac{3}{4}$  in.

Lengths:  $\frac{1}{2}$ ,  $\frac{3}{4}$ , 1,  $1\frac{1}{4}$ ,  $1\frac{1}{2}$ ,  $1\frac{3}{4}$ , 2,  $2\frac{1}{4}$ ,  $2\frac{1}{2}$ ,  $2\frac{3}{4}$ , 3,  $3\frac{1}{2}$ , 4 in.

**Figure 2-10:** Portion of a page from a (superseded) McPherson's Catalogue, illustrating:

- (a) a coarse thread bright steel setscrew and a fine thread brass setscrew plus table showing the sizes and threads in which they are available;
- (b) a square-head case hardened cup-point steel setscrew with table of available sizes and threads.

Note that the brochure gives details of available setscrew lengths and thread forms, listing BSW, BSF, UNF and UNC. Refer to the text and figures in the next section on **Standard V Threads** for an explanation of the meanings of BSW, etc.

## 2.2 Standard V threads

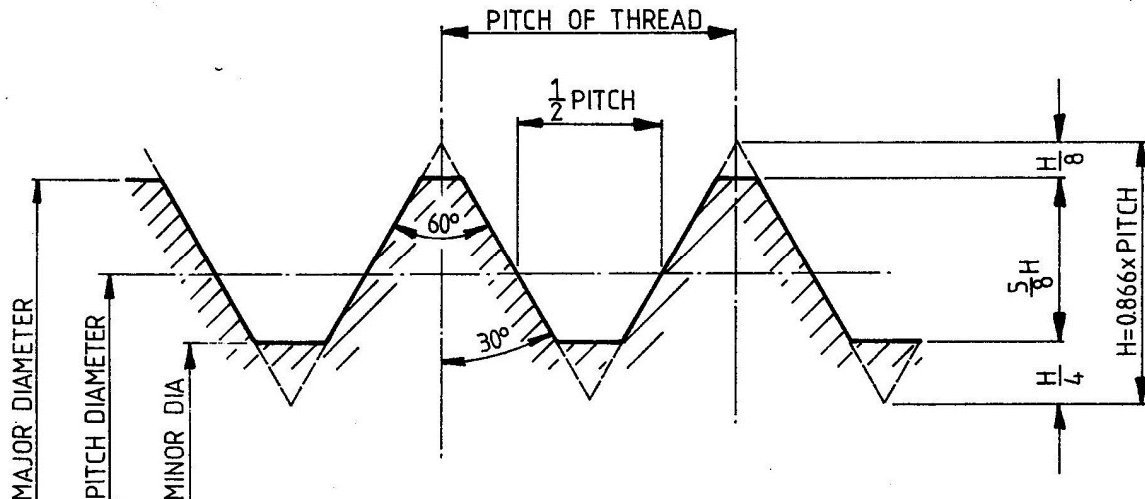
### 2.2.1 Root area of bolts

As is apparent from Fig 2-2 above, the cross-sectional area of a bolt calculated from the minor diameter (called the **ROOT AREA**) is significantly smaller than an area calculated from the major diameter. This means that the presence of the thread decreases the ability of a bolt to carry tensile loads. Hence for a bolt, the thread must be a compromise: it must be deep enough to achieve adequate thread strength, yet as shallow as possible to preserve adequate cross-sectional area.

Many different V-thread standards have been used over the years, originating in different countries and used for different purposes in different industries. Metric screw threads, based on Australian Standard 1275 - **Metric Screw Threads for**

**Fasteners**, are now the accepted Australian standard. These conform to the International Standards Organisation (ISO) Standard for threads, used throughout most of the industrial world.

### 2.2.2 Metric threads



**Figure 2-11:** Diagram of the profile of a standard metric thread, showing thread terminology. The profile is essentially a 60° V form with truncated crests and troughs, with the thread pitch (distance between adjacent peaks) related to the bolt diameter.

Reproduced from *Mechanical Technology 1*, NSW Dept. of Technical and Further Education.

**Table 2-1:** Bolt diameter and standard thread pitch for some common Metric bolt sizes.

Bolt diameter (mm)	3	4	5	6	8	10	12	16	20	24
Thread pitch - coarse	0.5	0.7	0.8	1	1.25	1.5	1.75	2	2.5	3
Thread pitch - fine					1.0	1.25	1.25	1.5	1.5	2.0

Table 2-1 above shows the pitch of the Standard Metric coarse and fine series threads. The pitch is related to the bolt diameter.

Metric threads are specified as in the following example.

	M12 × 1.25	
M = Metric Series	12 = Diameter of Thread in mm	1.25 = Thread Pitch in mm i.e. fine series

### 2.2.3 Other V threads

As previously mentioned, metric threads are the Australian standard and should be specified on new equipment, unless there are very good reasons for not doing so. However, much of the equipment still in use in Australia uses earlier thread systems and students need to be aware of these systems and their characteristics.

**British Standard Whitworth (B.S.W.):** is an Imperial thread, Coarse series, and was widely used in Australia prior to World War II.

**British Standard Fine (B.S.F.):** is fine pitch version of B.S.W., somewhat less generally used than Whitworth.

**British Association (B.A.):** is a fine thread which is mainly found in small sizes in instruments.

**National Coarse (N.C.):** was the standard American thread, and is similar in many respects to B.S.W.

**National Fine (N.F.):** was the standard American Fine thread.

**Unified National Coarse (U.N.C.):** was introduced during the Second World War by Britain, Canada and the United States to standardise on a common thread form. U.N.C. is very similar to N.C.

**Unified National Fine (U.N.F.):** is the standardised fine thread with history similar to U.N.C.

**Non-Standard Metric Threads:** prior to the setting up of the International Standards Organisation (ISO), each European country had its own standard for metric threads. Hence threads on European machinery built before about 1970 are not necessarily standard metric form or pitch.

All the threads listed above (with the exception of metric threads) are in Imperial units, i.e. inches. Most of these threads are specified by the thread diameter in inches, the thread form or series and the number of threads in one inch of thread length, i.e. threads per inch (TPI). Examples specifying such threads are

$$\frac{1}{2}'' \text{ BSW } 12 \text{ TPI}$$

$$\frac{3}{8}'' \text{ UNF } 24 \text{ TPI}$$

$$\frac{9}{16}'' \text{ UNC } 12 \text{ TPI}$$

B.A. threads are specified simply as 8BA, 10BA, etc.

### A PRACTICAL NOTE

It may save you embarrassment some time to know that spanner sizes for all thread forms other than the Imperial threads (BSW, BSF, and BA) are measurement “across flats”, i.e. a “half inch spanner” is used on a bolt which

has a hexagon which measures 0.5 inch across flats. Similarly, a 12 mm metric spanner fits a 12 mm across-flats hexagon. However, a spanner size described as “half inch Whitworth” is the dimension of the nut which fits on a half inch diameter Whitworth bolt. The nut (and hence the spanner) actually measure just over 23 mm (7/8 inch) across flats.

## 2.3 Bolt materials

Bolts are made in a wide variety of materials, e.g. brass, stainless steel, copper and various grades of carbon and alloy steel. However the great majority of bolts are made of some form of steel and steel bolts are used unless there is good reason (e.g. a corrosive environment) to specify a different material. Where there is likely to be exposure to the elements, steel bolts can be protected by galvanising or other surface treatment.

Tensile strength is an important criterion for bolt materials and is the parameter used to specify the bolt's load-carrying capacity. Just a few examples of available steel bolts of various strength ratings are given in the table below.

**Table 2-2:** Steel bolt materials, strengths, **Metric grades** and general uses.

<b>Bolt Material</b>	<b>Tensile Strength</b>	<b>Bolt Grade (METRIC)</b>	<b>Uses</b>
0.2% carbon steel	300 MPa	—	Black bolts. General, non-critical use
0.4% carbon steel	550 MPa	5	Good quality work, but not critical
0.4% carbon steel, heat treated	800 MPa	8	High quality work in critical applications
0.4-0.5% carbon low alloy steel, heat treated	1000 MPa	10	More critical applications, and where size and weight are critical
0.4-0.5% carbon low alloy steel, heat treated	1200 MPa	12	Highest quality which is readily available

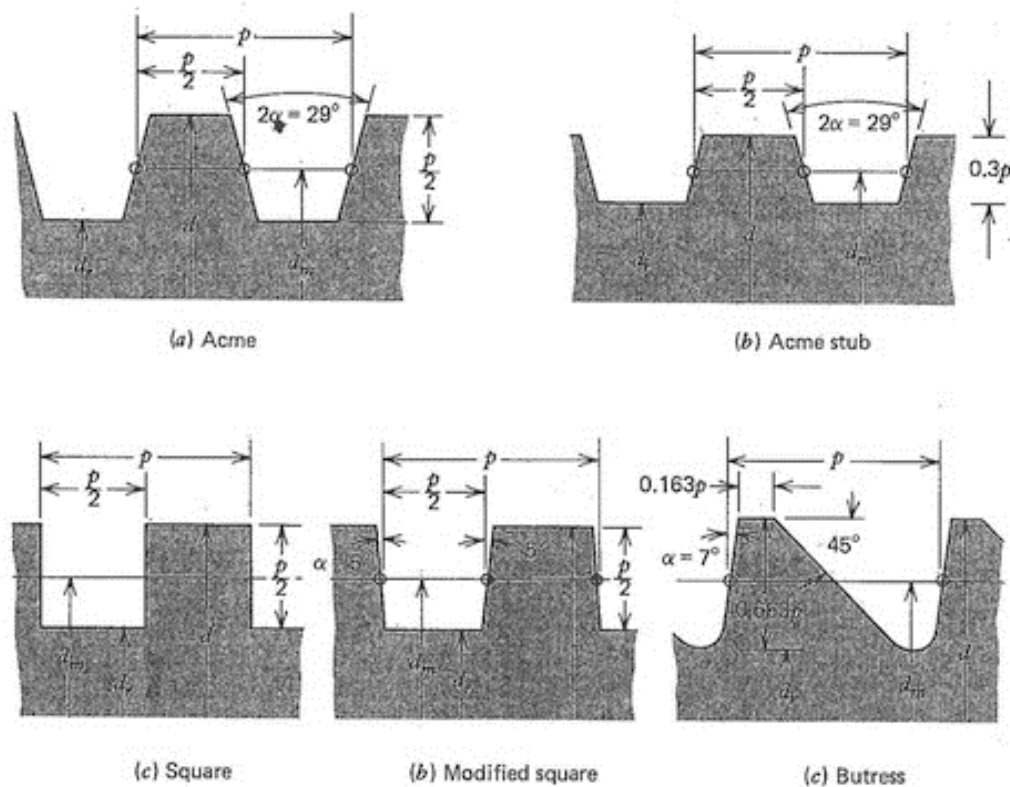
### CAUTIONS!

1. **These are metric grades.** A Grade 8 bolt in the metric system is roughly equivalent to Imperial Grade 5.

2. Strengths given are indications only. Always refer to manufacturer's specifications.
3. High quality bolt gradings are frequently given as, for example, grade 12.9. This specifies a material with (ultimate) tensile strength of 1200 MPa and yield strength of  $0.9 \times 1200 = 1080$  MPa.

## 2.4 Other thread forms

V threads are the standard used on most threaded fasteners and are by far the most common. There are several different V thread systems or standards which have been or are in popular use, some of which were described above. However, other thread profiles are in use for special purposes. Those shown below are more properly classed as power transmission elements rather than fasteners. However, the emphasis here is on their characteristics as threads.



**Figure 2-12:** Showing the thread profiles of a number of threads used for special purposes, generally involving power transmission rather than fastening. The precise thread profiles are not the issue here, just the general shape and corresponding function.

Juvinall, R C, Fundamentals of Machine Component Design, Wiley 1983, page 279.

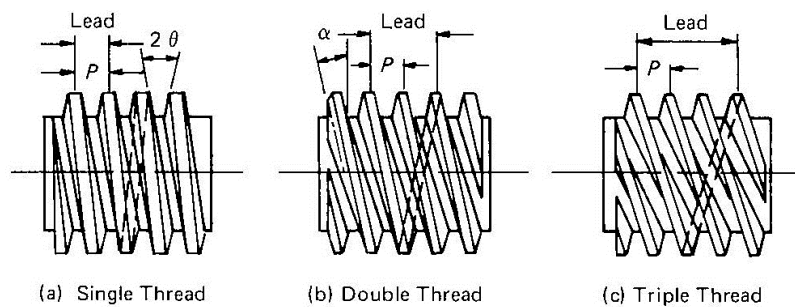
Due to its profile, the **SQUARE THREAD** is more difficult to machine than a V thread and is only used where strength and wear resistance make it worthwhile.

The **ACME** and **BUTTRESS** threads are easier to machine. The **BUTTRESS** thread can be used only where the applied loading is always in one direction. It is sometimes used in quick-adjust bench vices, in combination with a **SPLIT NUT**.

When the two halves of the split nut are moved apart, the gap in the jaws of the vice can be adjusted simply and quickly by sliding the moveable jaw without having to use multiple rotations of the handle.

#### 2.4.1 Multi-start threads

All the threads mentioned so far have been single-start threads. In other words, they have one single helix. If we wish to make the helix angle very large (e.g. to move a nut very rapidly along a thread) a single start thread becomes disproportionately large and the shaft has only a small root area. The difficulty may be overcome by using multi-start threads. Two-, three-, four- and six-start threads are possible.



**Figure 2-13:** An illustration of single-, double- and triple-start threads with an Acme profile. It may be observed that while the **THREAD PITCH** remains unchanged, the **LEAD** or distance a nut would move per turn has been doubled or tripled in the two- and three-start threads respectively.

Deutschman, A D, Michels, W J and Wilson, C E, Machine Design Theory and Practice, Macmillan, 1975, page 758.

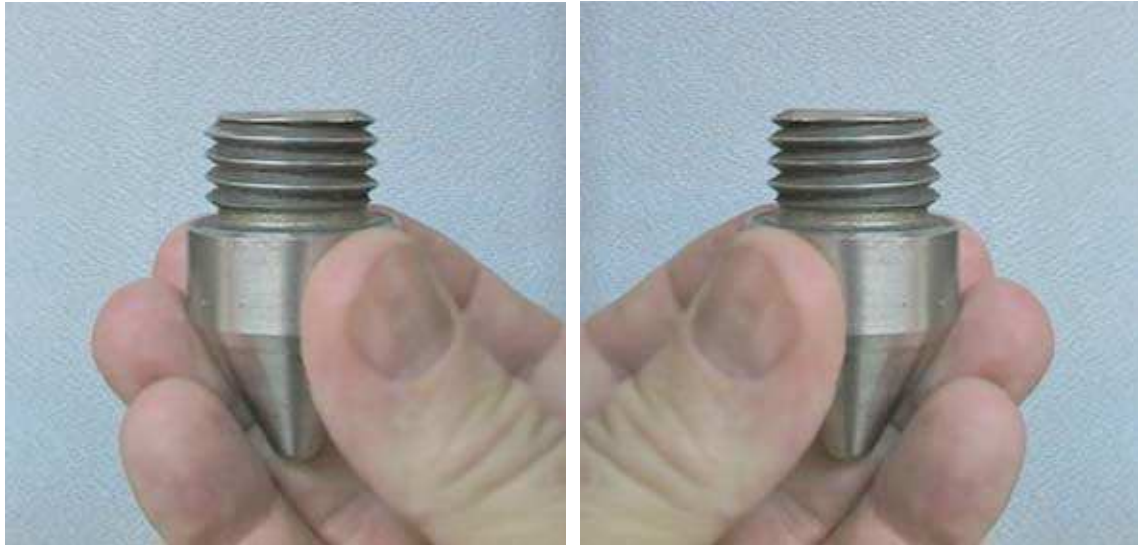


**Figure 2-14:** An example of a multi-start thread can be found on some hand operated **BENCH FLY PRESSES** (left). The large **FLYWHEEL** on top of the press is rotated by hand and, as it rotates, raises or lowers the press tool (the red portion of the press) by means of the **MULTI-START THREAD**. The kinetic energy stored in the rotating flywheel is utilised to carry out operations such as light riveting or staking. <http://product-image.tradeindia.com>

An example of multi-start threads closer to home may be found on some food jars. A major advantage is that multi-start threads can be made larger and easier to produce by processes such as injection or blow moulding. A three-start thread, for example (Fig 2-14, right) means that the thread must begin to engage within  $120^\circ$  of rotation of the cap or lid, compared with up to  $360^\circ$  for a single start thread. Furthermore, tightening can be completed with smaller rotation, probably no more than a single “twist of the wrist”. Some manufacturers of food containers choose up to what are effectively four-start threads.



### 2.4.2 Left-hand and right-hand threads



**Figure 2-15:** *Left:* An example of a **left-hand** helix or **left-hand** thread. *Right:* An example of a standard **right-hand** helix or **right-hand** thread.

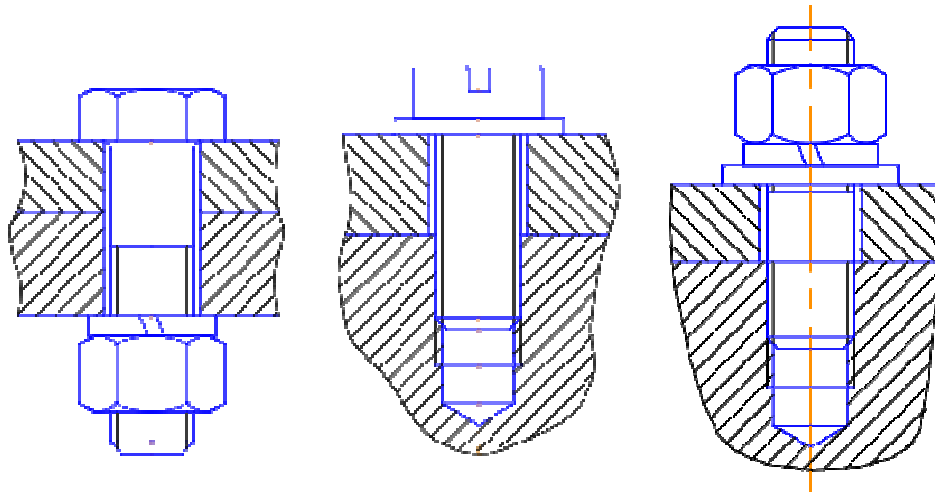
<http://www.sailingservices.com/references/threaddirect.htm>

Most of the threads used in engineering are of the standard **RIGHT-HAND** helix. However, there are sometimes good reasons for choosing a **LEFT-HAND** helix.

The threads on some wheel nuts, particularly on the left-hand side of some trucks, may use a **LEFT-HAND** thread. The usual reason given is that the nuts project from the wheel and, by coming into contact with roadside objects, right-hand threads may tend to be loosened.

A different application is where the aim is to prevent incorrect connections for safety reasons. For example, the threads on the **oxygen** bottles used in oxy-acetylene welding are **RIGHT-HAND** threads, while the threads on the **acetylene** bottles are similar in size but are **LEFT-HAND** threads, so it is impossible to connect the bottles incorrectly.

## 2.5 Screw-threaded assemblies

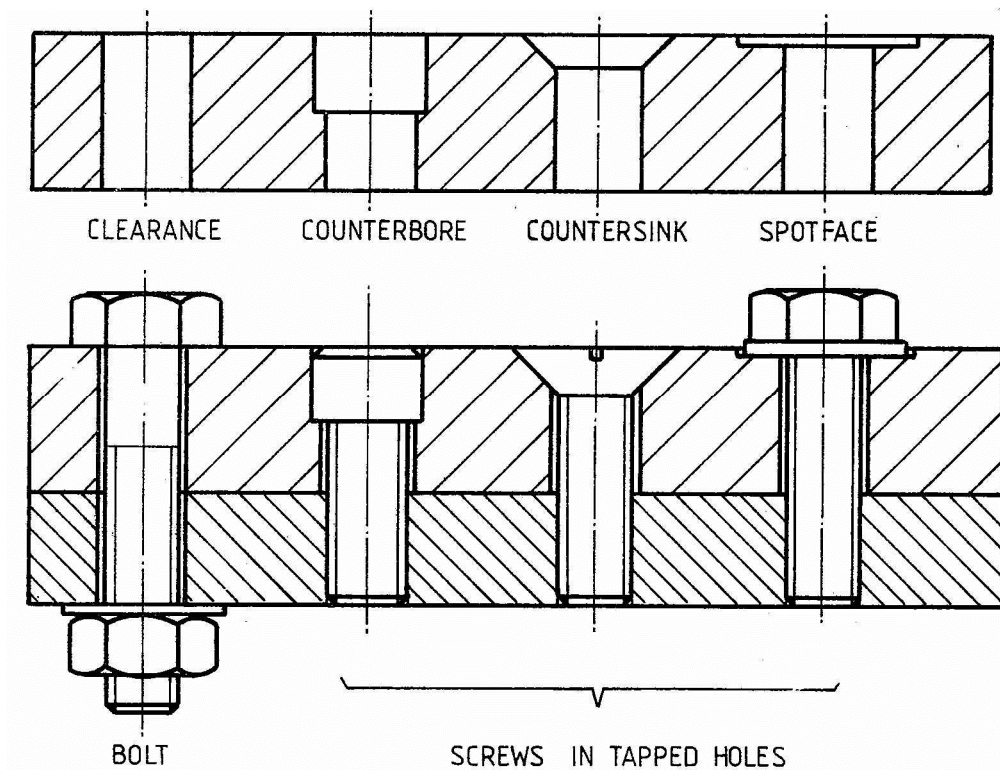


**Figure 2-16:** Three methods of making threaded fastener joints. Students are expected to be able to recognise the standard engineering-drawing conventions associated with threaded fasteners and joints.

[http://en.wikipedia.org/wiki/Bolted\\_joint](http://en.wikipedia.org/wiki/Bolted_joint)

The left-hand diagram in Fig 2-16 shows a joint made using a bolt and nut with the bolt passing through a clearance hole in the parts to be joined. The centre diagram shows a screw passing through a clearance hole in the upper part with a tapped (threaded) hole in the lower part. The right-hand diagram uses a threaded stud (i.e. a bolt with no head and two separate lengths of thread). The upper part has a clearance hole and the lower part has a tapped (threaded) hole. It is usual for the stud to be screwed into the threaded hole **to the end of the thread on the stud** (as shown in the diagram) and then left in place, with the joint detached when necessary by removing the nut.

Studs (right-hand diagram in Fig 1-16) have some advantages compared with other fastening methods. The projecting studs can be used to locate and guide parts during assembly. The tapped hole takes up little space and the hole can be **BLIND** (i.e. not all the way through the component) which may avoid sealing problems. Studs are generally intended to be screwed as far as possible into the tapped hole in a component (i.e. right to the end of the threaded section of the stud, **not** the end of the threaded section of the hole) and to remain there as a semi-permanent attachment. The joint is detached by unscrewing the nut from the exposed end of the stud. Wear and tear of the tapped hole is thereby avoided. Disadvantages include greater cost than for a bolt and nut, long projecting studs are easily damaged, and studs are difficult to lock in severe vibrating conditions.



**Figure 2-17:** Details of some common joint configurations for threaded fasteners. Reproduced from *Mechanical Technology 1*, NSW Dept. of Technical and Further Education.

Fig. 2-17 shows some commonly used screwed-fastener assemblies, and the holes machined in the components prior to fitting the screwed fasteners (see top section of Fig 2-17). The bolt with flat washer and nut has already been discussed. Note that both the bolt head and the nut project from the surfaces of the components. This may be a serious disadvantage in some applications (e.g. where space is restricted or the assembly is rotating and the protruding heads could be a catch point) and can be avoided by a different choice of fastener.

An alternative is to replace the threaded nut with a suitably sized internal helix (i.e. a thread similar to that in a nut) machined into one of the components to be fastened (2nd, 3rd and 4th examples of Fig. 2-17). The process of forming the internal thread in this way is called **TAPPING** and the hole is then a **TAPPED HOLE**.

The advantages of a tapped hole compared with a nut and flat washer are:

- Fewer components are required.
- There is no nut to get lost.
- One side of the joint can be made flush.

The disadvantages are:

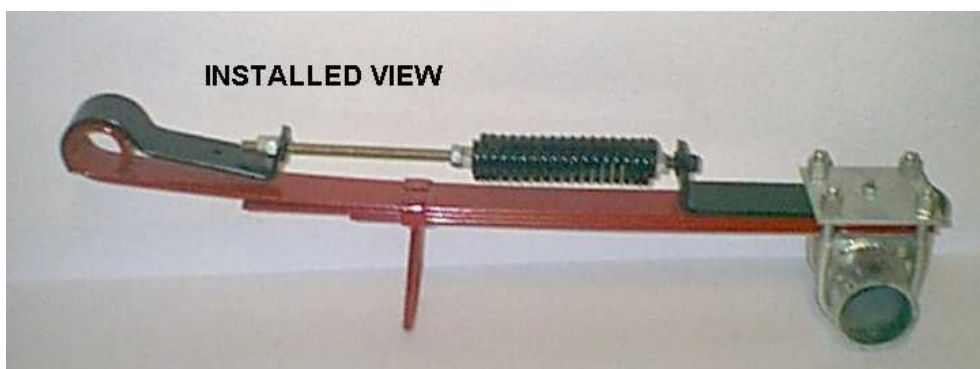
- If the internal thread is damaged, the part may have to be scrapped, but see “Helicoils” below.

- Threads tapped into materials such as aluminium or cast iron are weaker than the threads on the setscrew or a nut.
- It is more costly to have to cut (i.e. tap) a thread in the component rather than buy the thread ready-made in a nut.

Fig. 2-17 also shows ways in which the joint can be made flush at the head of the fastener. For example, the second and third arrangements in this figure use a capscrew (with internal hexagon) recessed into a counterbored hole and a countersunk screw respectively.



<http://www.browardtrailer.net/TransportTrailerPhotoGalleryChoice.html>



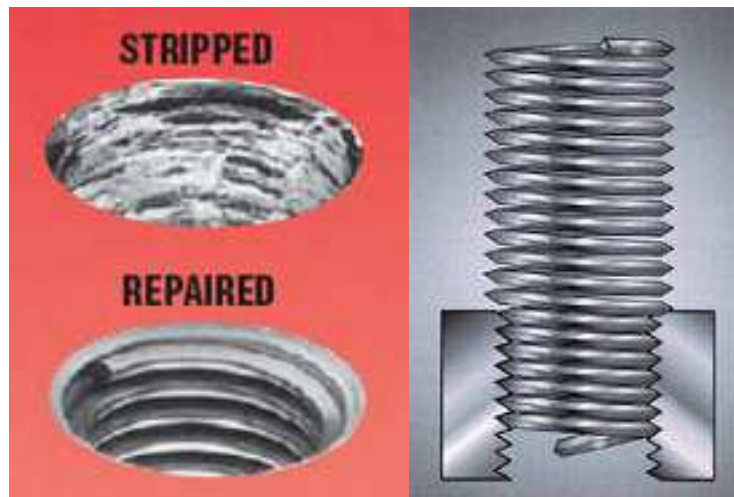
[http://www.roadmasterok.com/images/DEMO\\_PIC.JPG](http://www.roadmasterok.com/images/DEMO_PIC.JPG)

**Figure 2-18:** Practical examples of the use of **U-BOLTS** to secure a **LEAF SPRING** to a trailer axle. In each case, two round U-bolts (see Fig 2-8) are used to clamp the leaf spring to an axle or similar member.

**FOR KEEN STUDENTS**

It is now accepted practice to “reclaim” a damaged internal thread by the use of a proprietary device known as a Helicoil. In essence, the damaged internal thread is drilled out, and the hole is re-tapped (threaded) to suit a special Helicoil insert. Then the Helicoil is “wound” into place, leaving the hole with a new thread of the same size and pitch as the original.

A major advantage of Helicoils is that if the original thread is in a weak material such as cast iron or aluminium, the repaired joint is actually stronger than the original because the thread in the weak material is now of a larger diameter than the original. In fact, Helicoils may be fitted from new where experience suggests that an ordinary tapped hole will be a cause of weakness.



<http://www.helicoil.com.sg/>



**HeliCoil**  
Screw Thread  
Inserts

**Figure 2.19:** Installation of Helicoil replacement thread.

<http://www.helicoil.com.sg/HeliCoil-Installation-Instructions.htm>

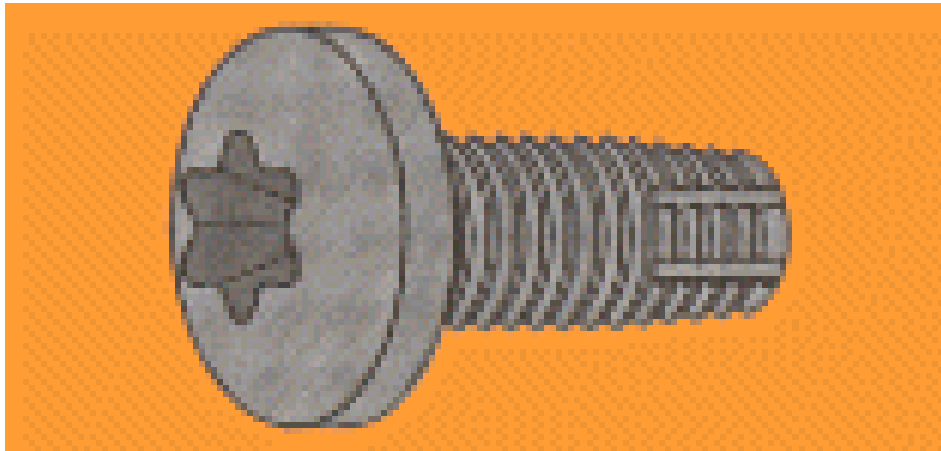
## 2.6 Other detachable fasteners

There are many available forms of fastener in this group. Self-tapping screws are amongst the most important and are widely used in general engineering.



**Figure 2-20:** Self tapping screws, round head and hexagonal head. These screws are screwed into pre-drilled holes in sheet metal, plastic or timber and cut their own coarse thread.

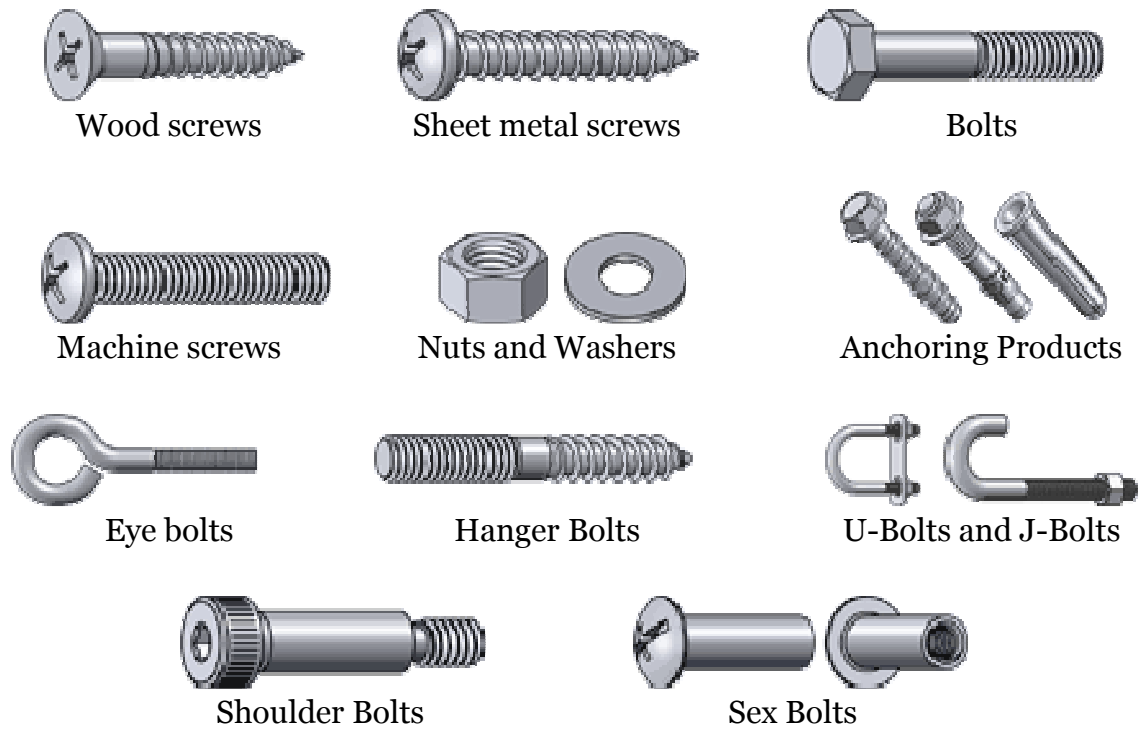
[http://www.adfasteners.com/images/self\\_tapping\\_screws](http://www.adfasteners.com/images/self_tapping_screws)



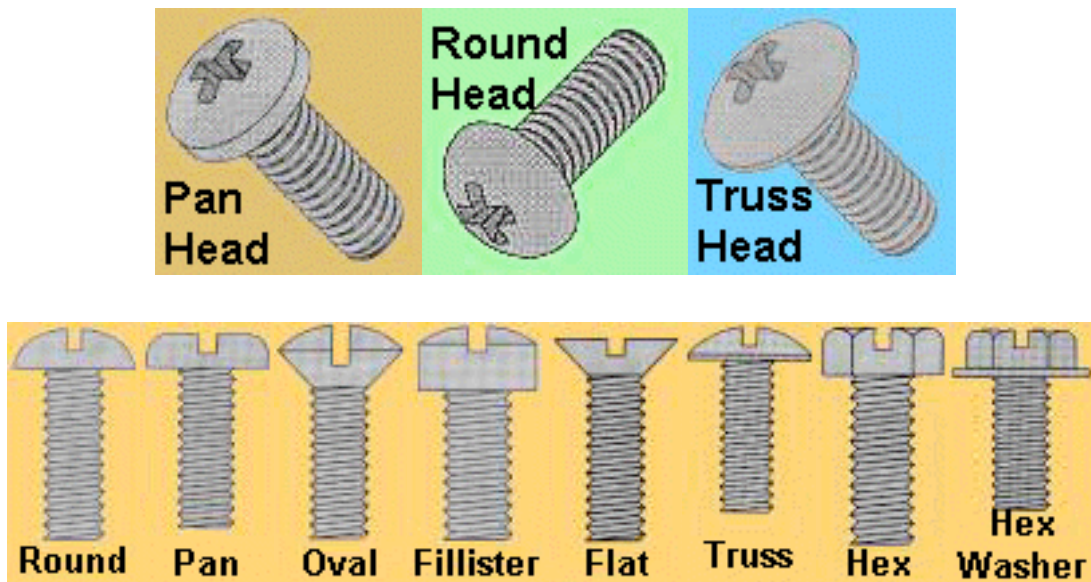
**Figure 2-21:** An example of a different type of self-tapping screw known as a Torx thread cutting fastener. It requires a pre-drilled hole, but produces a much finer thread than a normal self-tapping screw and can be used to tap into thicker materials. Most of the thread-cutting is done by the sharp edges on the two slots visible near the end of the screw. Note the slight taper on the end threads, assisting the cutting process.

<http://www.aaronstorxscrews.com/ThreadCuttingScrews.htm>





**Figure 2-22:** Further examples of types of screwed fasteners commercially available. <http://4wheeldrive.about.com>



**Figure 2-23:** Some additional examples of machine screws and available heads for machine screws to suit different applications. <http://www.aaronsmachinescrews.com>



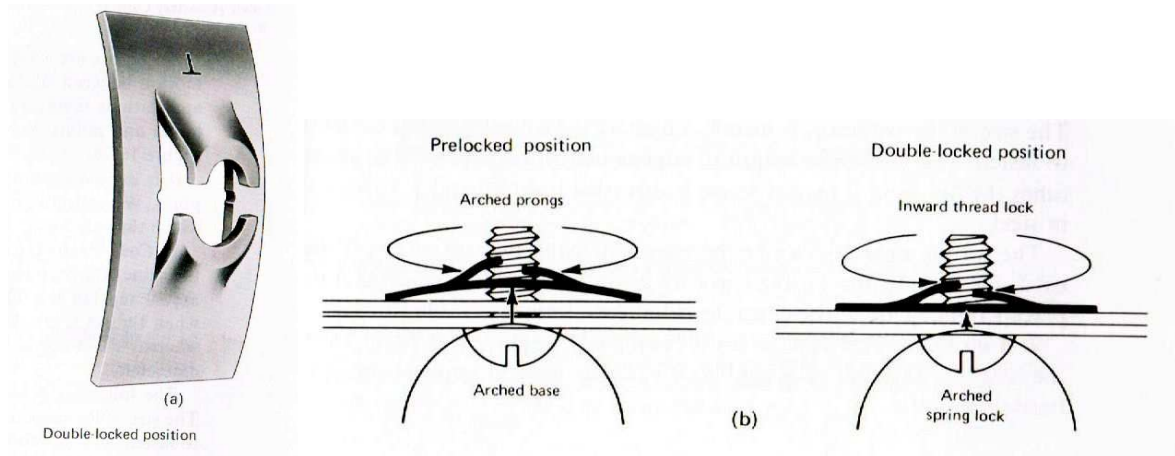
**Figure 2-24:** Speed Nuts® and Speed Clips®.

(Courtesy of Engineered Fasteners, a division of the Eaton Corporation.)

Reproduced from R.H. Creamer, *Machine Design*, 1984, Addison-Wesley.

In mass production applications, self-tapping screws may be used in conjunction with Speed Nuts or Speed Clips, some examples of which are shown in Fig. 2-24. The advantages with using speed nuts or speed clips is that the nut or clip can be clipped into place during pre-assembly. The nut or clip is usually made from spring steel, which is stronger than the material being assembled, and the nut or clip usually embodies a self-locking feature, as illustrated in Fig 2-25 below.



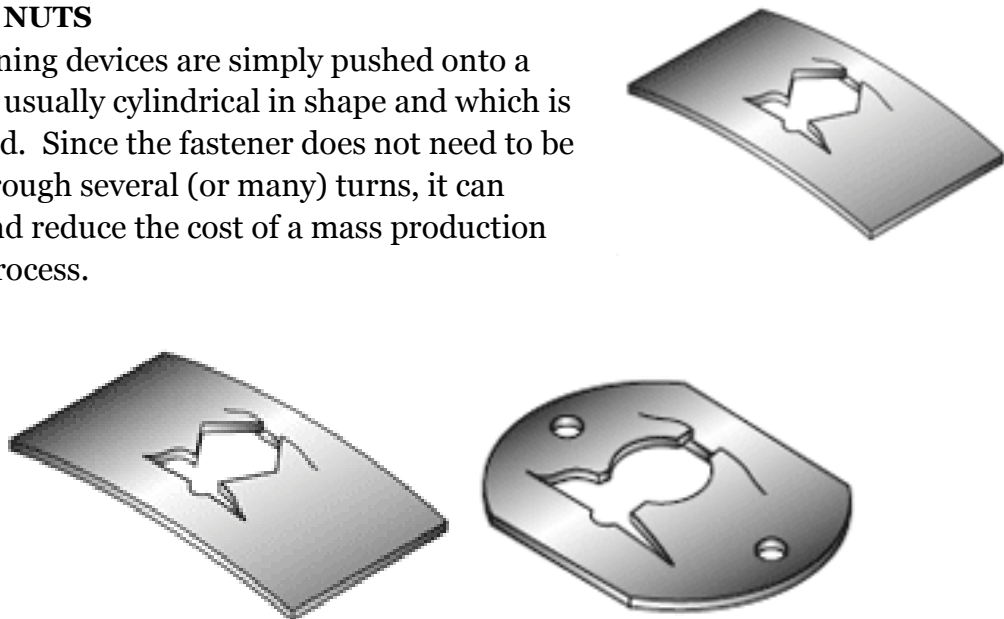


**Figure 2-25:** A speed nut (*left*) and that nut showing the self-locking principles used (*right*).

Deutchman A D, Michels, W J, Wilson, C E: Machine Design Theory and Practice, Macmillan, 1975 page 801.

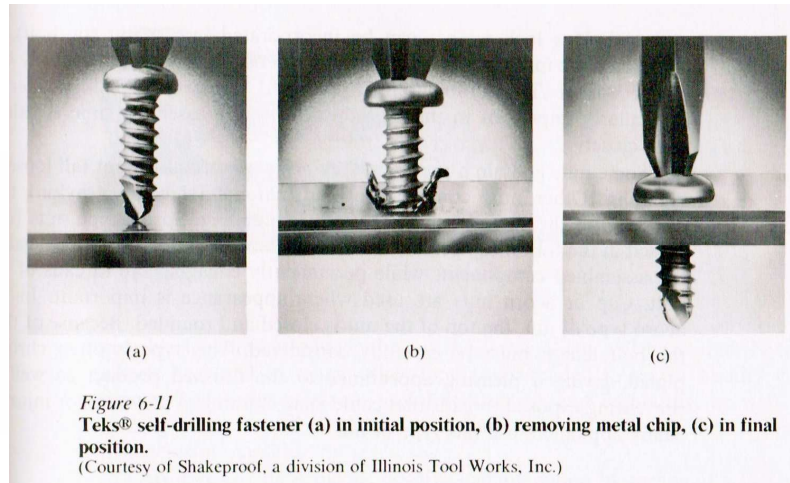
### PUSH-ON NUTS

These fastening devices are simply pushed onto a protrusion, usually cylindrical in shape and which is not threaded. Since the fastener does not need to be screwed through several (or many) turns, it can speed up and reduce the cost of a mass production assembly process.



**Figure 2-26:** Push-on nuts used for rapid assembly where there is no thread on the part to be fastened. The raised lugs tend to dig into the protrusion and resist loosening. The diamond shape aperture (left) requires the lowest pressure to install. Push-on nuts are to be regarded only as a light-duty fixing.

<http://www.shakeproof.com>



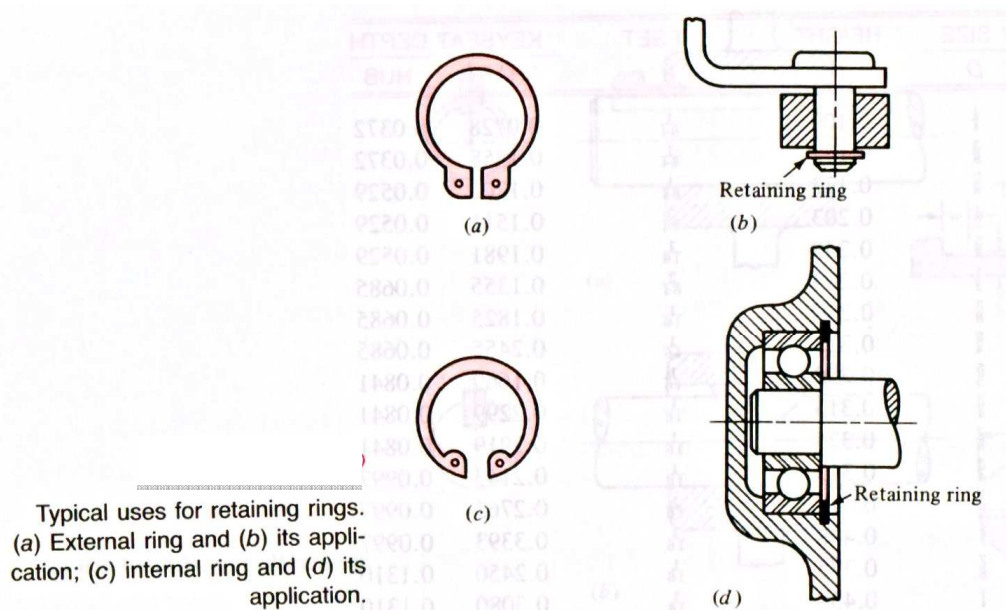
**Figure 2-27:** Examples of self-drilling self-tapping screws. A popular trade name for these screws is **TEKS**. <http://www.thread-rite.com/teks/>

## CIRCLIPS



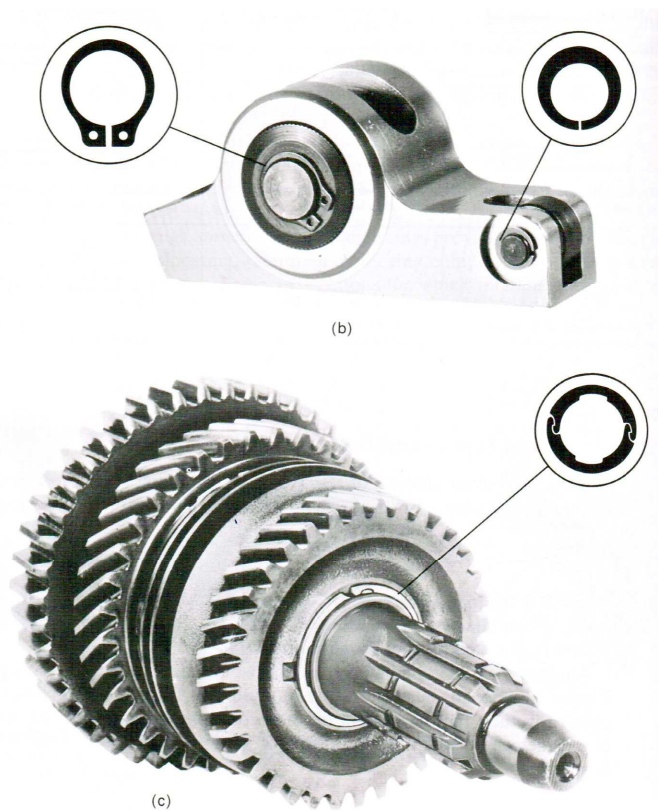
**Figure 2-28:** Examples of **CIRCLIPS** (also known as **SNAP RINGS** or **RETAINING RINGS** or **C CLIPS**), and an **E clip** (bottom right).  
<http://www.lexic.us/definition-of/circlip>  
(See also roll pins and grub screws – Project 6 - *Power Transmission Elements*).

Circlips are spring steel rings which fit (“snap”) into machined grooves to provide axial location. The “lugs” with small holes allow special pliers to be used to expand or contract the ring so it can snap into its groove.



**Figure 2-29:** Typical uses of **CIRCLIPS** or **RETAINING RINGS** to provide axial location of components. Note the different location of the lugs to enable fitting of internal and external circlips.

Shigley J E and Mischke C R Mechanical Engineering Design McGraw Hill International  
 6E 2003, ISBN 0-07-008303-7



**Figure 2-30:** Further illustrations of different applications of circlips.

Deutchman A D, Michels, W J, Wilson, C E: Machine Design Theory and Practice, Macmillan,  
 1975 page 808.

Typical uses of circlips include:

- On a shaft or external diameter to provide axial restraint for a component;
- Inside a cylindrical bore, holding a bearing or other component into its housing;
- Holding short shafts or pins axially in position;
- Holding a bearing axially on its shaft;
- Carrying axial load from the helical gear.

## 2.7 Locking of fasteners to prevent loosening in service

Before leaving detachable fasteners, one further aspect must be considered. It is often necessary to ensure that a threaded fastener will not loosen in service. Loosening is particularly likely to occur in applications where the joint is subjected to severe vibration, e.g. engines in general, motor vehicles, aircraft, etc. Considerable design effort has gone into developing effective methods of **LOCKING** threaded fasteners to prevent loosening.

### 2.7.1 Locking nuts and lock washers

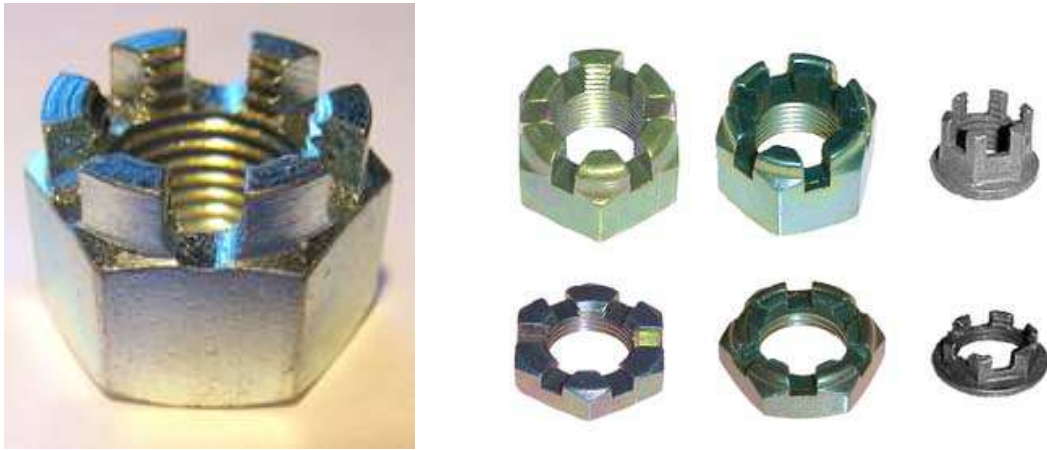
Numerous types of nuts and washers have been developed for different applications and different purposes.



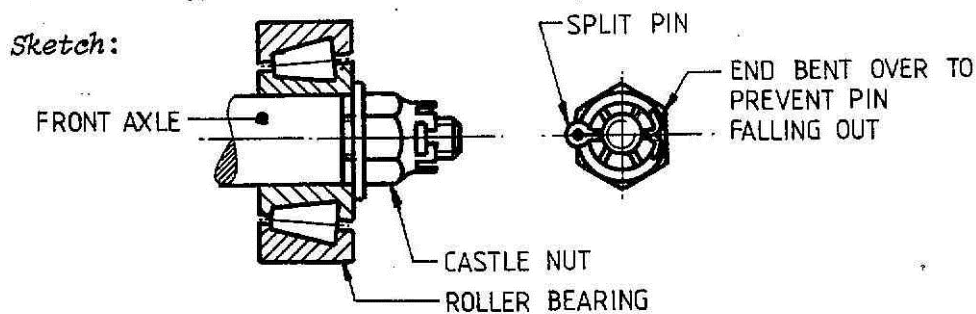
**Figure 2-31:** *Left:* A type of **SELF-LOCKING NUT** known as a **NYLOC NUT**. The free end of the nut is recessed and is fitted with a swaged-in nylon insert. The inside diameter of the nylon grips the thread of the bolt and provides frictional resistance against loosening. *Right:* Various types of nut, including wing nut (top), square nut, self-locking nut (centre) and a slotted nut (see also Fig 2-32).

<http://www.nylocknut.com>





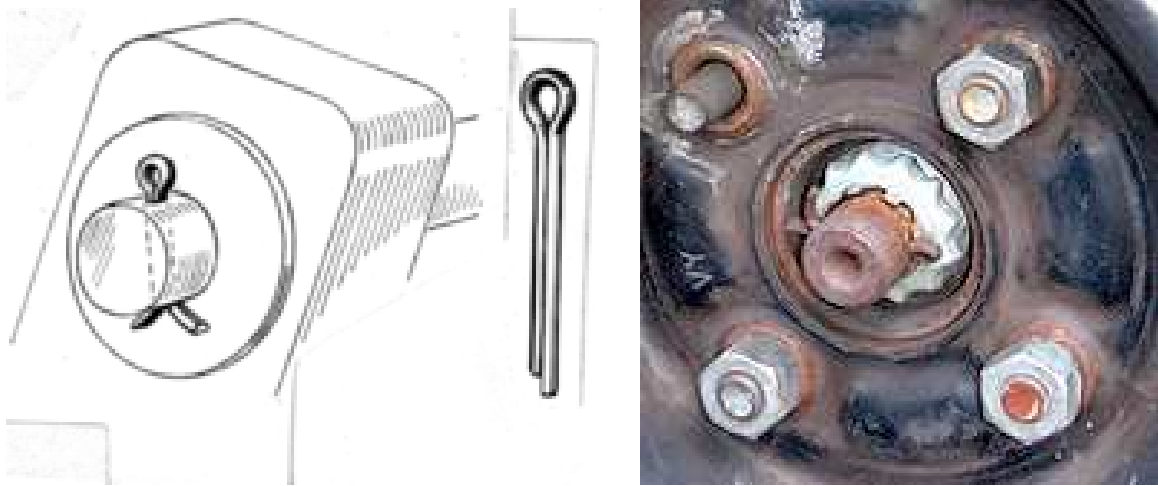
**Figure 2-32:** *Left:* A type of locking nut known as a **CASTELLATED NUT** or **CASTLE NUT** (a bit like the ramparts of a castle). *Right:* More examples of castellated nuts, some clearly intended for very light duties. The lower left nut in this group of six has no castellations and is called a **SLOTTED NUT**. <http://www.boltdepot.com/nuts.aspx>



**Figure 2-33:** An example of the use of a **CASTLE NUT** and **SPLIT PIN** to secure or lock the adjusting nut on the front wheel bearing of a motor car. The bearing shown is one of a pair of **TAPERED ROLLER BEARINGS** ( See Project 5 – Shafts and Bearings for further details of bearing types).

Reproduced from *Mechanical Technology 1*, NSW Dept. of Technical and Further Education.

In Fig 2-33, a **SPLIT PIN**, passing through a hole drilled in the axle, has been used to lock the castle nut in the desired position on its thread. In this application, the nut is not fully tightened and is used as a means of adjustment of the axial clearance of the tapered-roller bearing. The split pin is a means of securing the nut in the desired position once adjustment has been completed. In cases such as this, where a nut is used for adjustment purposes, ensuring that the nut does not move is crucial – if the nut loosens, the wheel assembly falls off; if the nut tightens, the bearings are “squeezed”, overheat and eventually seize. In view of their important role, it is good practice not to reuse split pins.



**Figure 2-34:** Further examples of the use of split pins for locking purposes:–

*Left:* Used with a flat washer to hold a link onto a shaft or axle while allowing the link to pivot freely. *Right:* A split pin used in real life on the front axle of a motor car to prevent rotation of a special **LOCK WASHER** which in turn prevents rotation of the hexagonal nut which holds the wheel bearing in place. In this example, the special lock washer can be pressed at little cost from sheet steel and the nut can be a plain hexagonal nut, avoiding the cost of a slotted or castellated nut.

[http://en.wikipedia.org/wiki/Bolted\\_joint](http://en.wikipedia.org/wiki/Bolted_joint)



*Left:* Conical serrated lock washers, used with countersunk-head screws.

<http://www.tradekey.com/ks-serrated-lock-washers/>

*Right:* A flat serrated lockwasher with external teeth.

<http://www.foerch.co.uk/product.aspx>

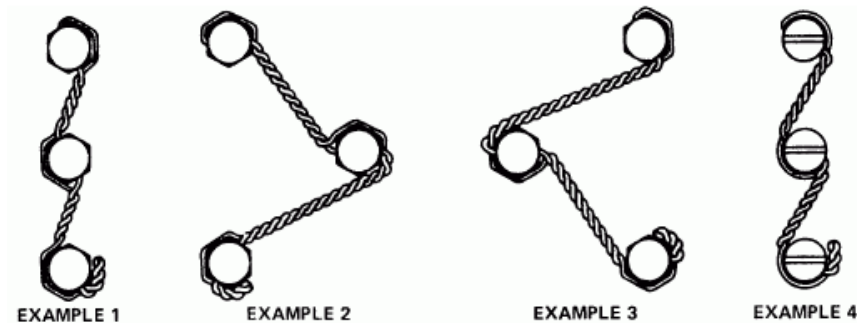


**Figure 2-35:** *Left:* **SPRING WASHERS** or **SPLIT WASHERS** which work by allowing tightening to proceed normally but prevent loosening by digging in the sharp edges of the split if the nut tends to loosen. The washers shown are for right-hand threads.

<http://smallparts.info/store/categories/washers+spring/all/>

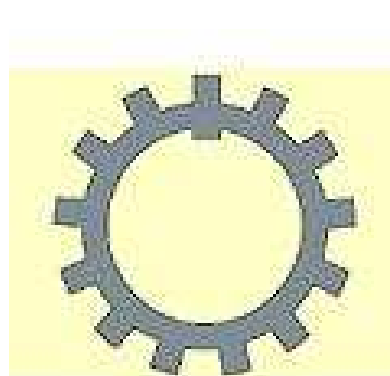
*Right:* **SERRATED LOCK WASHERS** or **STAR WASHERS** in which the points or teeth are twisted in a direction which allows normal tightening but dig into both surfaces if the nut tends to loosen. As shown in the right-hand group, the serrated teeth may be either external or internal and the washer may be coned to be used with a countersunk screw.

### 2.7.2 Other means of preventing loosening of threaded fasteners



**Figure 2-36:** Examples of **LOCK-WIRING** as a means of preventing loosening of screwed fasteners in service. Lock-wiring is commonly used on aircraft, where vibration is often present. Note that two strands of wire are normally twisted together, as shown, with one strand passing through a drilled hole in the head of the fastener. The wiring is installed in such a way that any tendency for the fastener to loosen would require stretching of the wires.

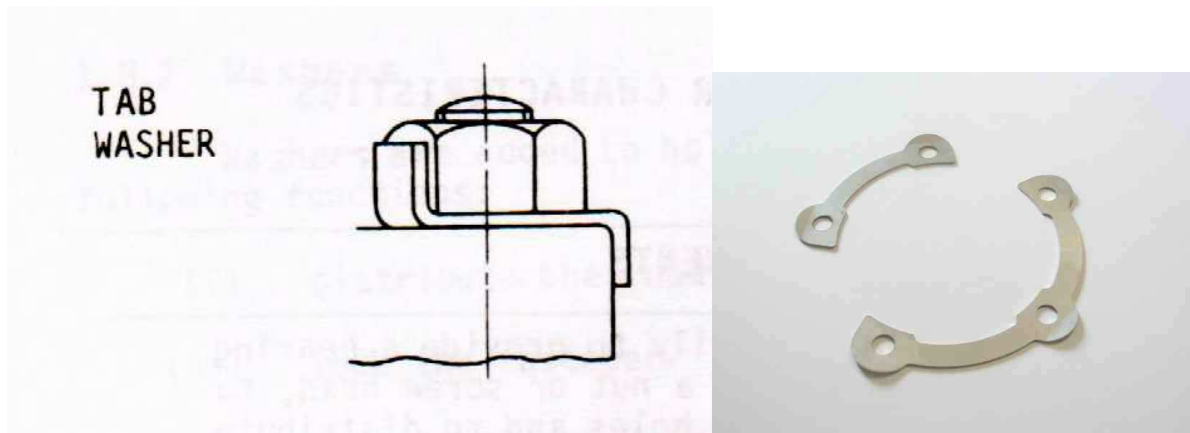
<http://www.byrongliding.com/lockwire.htm>



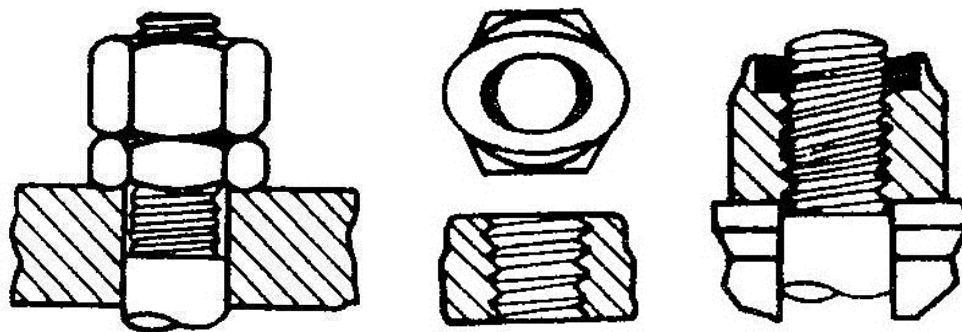
**Figure 2-37:** Examples of **LOCK TABS** or **TAB WASHERS** or **LOCK WASHERS**.

These washers are intended to fit onto a threaded length of a bolt or shaft in which a longitudinal slot called a **KEYWAY** has been machined. The central tab prevents rotation of the washer on the shaft and one of the outer tabs is bent up to lock the nut in position. See Fig 2-38.

<http://www.smallparts.com.au/store> and <http://www.minibearings.com.au/store/categories/washers>



**Figure 2-38:** Left: A different style of **TAB WASHER** in which one tab is bent down over an edge of an assembly and a second tab bent up to lock the nut in position. Reproduced from *Mechanical Technology 1*, NSW Dept. of Technical and Further Education. Right: Lock plates, which are prevented from rotation by being fitted over two or three bolts. Nuts are locked by bending up the small tabs, similar to the arrangement in the left diagram. <http://bevelrubber.com.au/cart/index.php>



**Figure 2-39:** Alternative locking methods include: *Left:* the use of **LOCKNUTS** (or **JAM NUTS**), in which the first nut is used to tighten the bolt in the normal way, then a second nut is screwed onto the bolt and the second nut tightened hard up against the first. *Centre:* a deformed nut in which part of the nut is squeezed out of round so that the thread grips the bolt tightly enough to resist loosening. *Right:* A sectioned view of a Nyloc nut (see also Fig 2-31), showing the Nylon ring insert deformed into the thread to provide frictional drag if the nut tends to loosen. Reproduced from *Mechanical Technology 1*, NSW Dept. of Technical and Further Education

In recent years, the use of specialised adhesives (one trade name is Loctite) has become increasingly popular as a means of securing components together. Joints made with Loctite adhesives are generally intended to be detachable (although possibly with some difficulty in practice). A large range of adhesives has been developed, having a range of bonding strengths, to suit different applications.



There are two different adhesive systems and students would be wise to seek expert advice on which system and which specific compound to use.

- **CYANOACRYLATE ADHESIVES (CAs)**

These are acrylic resins which polymerise or cure rapidly when exposed to alkaline surfaces, such as most metals, using the trace amounts of water present to trigger rapid polymerisation. They generally have:

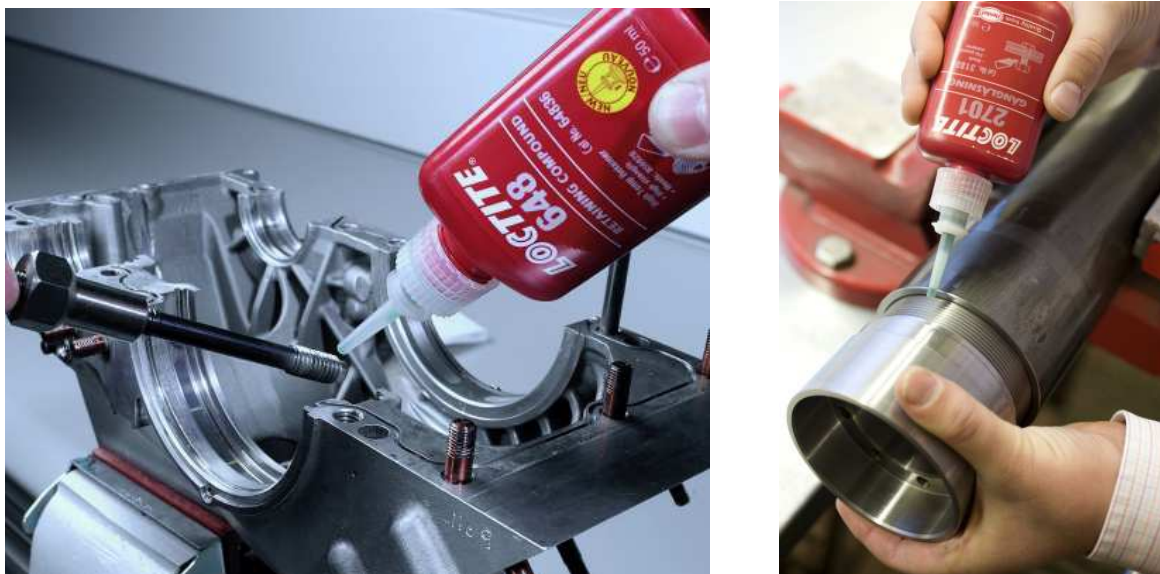
- *very high shear & tensile strengths*
- *very fast curing speeds (fixturing in seconds)*
- *the ability to bond to almost all materials*
- *good ageing resistance*

CAs can be used for both general purpose and specialised bonding applications that require fast fixturing.

- **ANAEROBIC ADHESIVES**

These remain liquid until isolated from oxygen in the presence of metal ions such as iron or copper.

Anaerobic materials are typically used in industry for applications such as threadlocking, threadsealing, retaining cylindrical assemblies & flange sealing.



**Figure 2-40:** Showing Loctite products being applied to the threaded section of a shouldered or stepped bolt in what appears to be a gearbox assembly (left) and to a sleeve being screwed into a cylindrical component (right). It is only necessary to apply a few drops of the Loctite compound.

<http://au.iloctite.com/en/loctite-products>



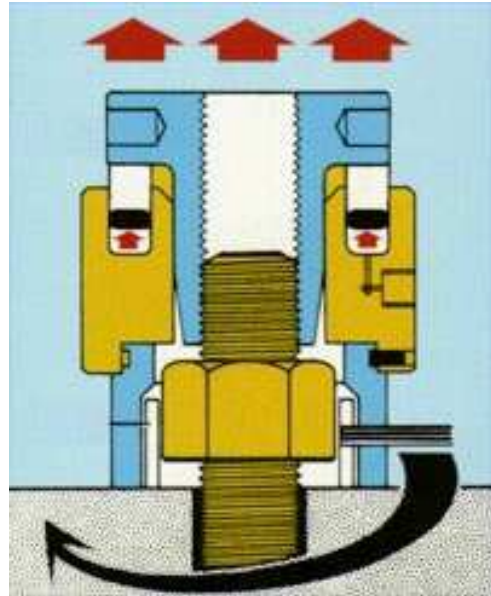
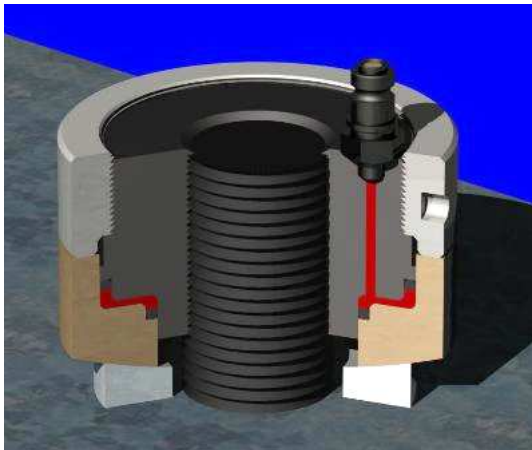
**Figure 2-41:** A setscrew which has been locked in place with a compound similar to Loctite, then forcibly unscrewed. The remains of the locking compound can be seen as the yellowish substance on the threads of the setscrew. In this particular application, the locking compound also served to seal the thread to prevent oil from inside the housing from leaking out along the spiral of the thread.

Photo from Alex Churches' files.

## FOR KEEN STUDENTS

### Hydraulic Nuts and Hydraulic Tensioners

With very heavy machinery, very large bolts and nuts are sometimes used – say of the order of 50-200 mm diameter. Very high torques are needed to fully tighten nuts of this size. This has led to the development of hydraulic methods of stretching the bolt.



**Figure 2-42:** *Left:* Sectioned view of a **HYDRAULIC NUT** in the process of tensioning the bolt. The nut assembly is first screwed onto the bolt until it takes up all the slack. Hydraulic fluid under high pressure (shown in red) is then applied, stretching the bolt. The top outer collar (light grey) can then be screwed down, after which the hydraulic pressure can be released. The hydraulic nut remains in position. Note the spherical washer under the nut, used to eliminate any bending which might over-stress the bolt.

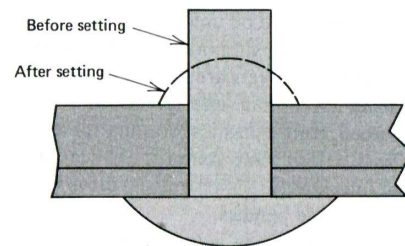
<http://www.nibtorque.com/id30.html>

*Right:* Sectioned view of a **HYDRAULIC TENSIONER**. First, the normal nut (yellow) is screwed as far as possible onto the bolt. The hydraulic tensioner (blue) is then screwed onto the protruding end of the bolt. Hydraulic pressure is then applied to stretch the bolt, after which the normal nut can be screwed down to hold the bolt in the stretched condition. The tensioner is then removed. <http://www.hydratight.com/en/products/tension/why-tension>

### 3 Non-detachable Fasteners

Non-detachable joints and fasteners include several widely different concepts. Connections described as "non-detachable" usually require partial destruction of the joint and/or its components to achieve separation.

#### 3.1 Rivets



**FIGURE 11.1.**  
Conventional solid rivet before and after setting.

**Figure 2-43:** *Left:* Examples of riveted joints on one of the four supporting legs of a water tower.

[http://www.texasescapes.com/Texas\\_architecture/Images/FayettevilleTXWaterTowerRivetsAndBraces1206JT.jpg](http://www.texasescapes.com/Texas_architecture/Images/FayettevilleTXWaterTowerRivetsAndBraces1206JT.jpg)

*Right:* Detail of “setting” a solid rivet. The rivet is first placed in position to hold two metal plates together. It is then deformed or “set”, forming a second “head”, thereby clamping the plates tightly together.

Juvinall, R C, Fundamentals of Machine Component Design, Wiley, 1983, page 331.

Rivets are similar in several respects to the bolt-and-nut connections previously described. A rivet, with a head already forged on one end, is passed through holes in two or more components. Then, instead of tightening a nut on a helical thread, the projecting end of the rivet is hammered or squeezed to form what is effectively a second "head" on the rivet. This process is called “**SETTING**”. A riveted joint can be

detached only by cutting off or otherwise removing one head of the rivet and driving out the remainder of the rivet.

### 3.1.1 Hot riveting

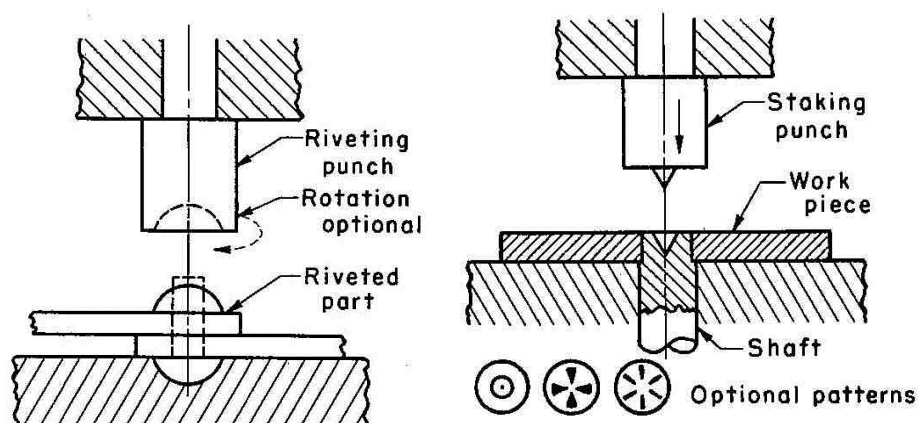
The Sydney Harbour Bridge has been constructed by hot riveting. Inspection of the structure, particularly from the lower levels where the arch is supported, reveals a wealth of engineering design features and is well worth a visit for general interest as well as part of this course. Many older pressure vessels, e.g. steam boilers, were made by rolling sheets of steel plate into half- or quarter-cylinders and hot riveting the sections together.

In hot riveting, the rivet is heated to bright red, placed in its hole and held firmly in position while the protruding end is hammered into the required shape. A special tool called a **RIVET SET** is used to shape the second "head" during hammering.

Hot riveting is claimed to produce very high clamping forces because the rivet shortens as it cools. However the process is very expensive (labour intensive) and is now seldom used. Modern pressure vessels, for example, are usually of welded construction rather than riveted, although this has only been made possible by greatly improved welding methods.

### 3.1.2 Cold riveting

Many smaller riveting processes are carried out with the rivet cold, using a press to deform the protruding end (Fig. 2-9). Cold processes are much easier to fit into a factory assembly line and cold riveting is still widely used in the manufacture of light engineering components.



**Figure 2-44:** *Left:* Method of fastening small parts by cold riveting, showing the use of a riveting punch to set the rivet. *Right:* Fastening a gear to a shaft by staking. For small production quantities, the hand fly press seen in Fig 2-14 might be used for either the riveting or the staking process.

Reproduced from E.P. DeGarmo, *Materials & Processes in Manufacturing*, 5th Ed., Macmillan, pages 399-400.



### 3.1.2.1 *Staking*

In the design of some engineering components, it may be possible to include small and relatively cheap features which greatly facilitate assembly. For example, Fig. 2-42 shows, on the left, a typical cold-riveting assembly process which uses a separate rivet. On the right, a small gear after assembly onto a shaft by the process described as **STAKING**. The conical end of the staking punch indents the end of the shaft and forces the material outwards, thereby securing the gear to the shaft. Note that the designer's forethought in designing the small step on the end of the shaft provides:

- Fixing method with no additional parts (low cost).
- Accurate radial alignment of the gear by the stepped diameter.
- Accurate axial alignment against the machined shoulder.

### 3.1.2.2 *Hollow rivets*



**Figure 2-45:** Examples of various types of hollow rivets, although some items in the left-hand group are actually small solid rivets.

<http://abcfasteners.com> <http://www.rivtool.com> and <http://www.chinafastener.com>

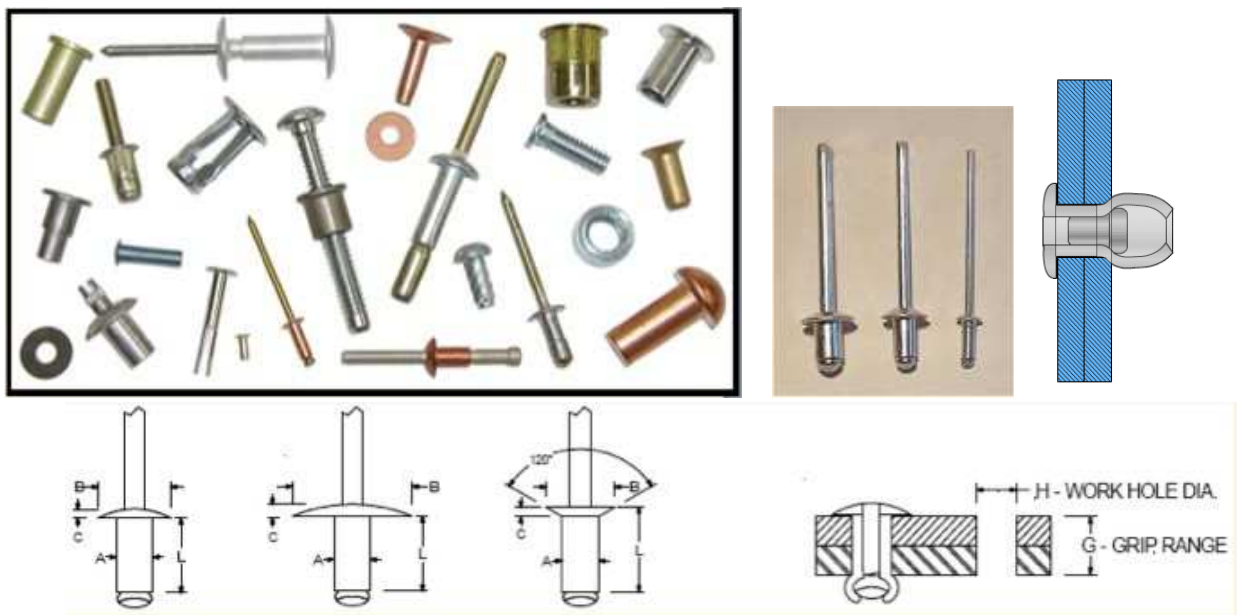
Hollow rivets are made in sizes up to about 6 mm diameter and lengths up to about 25 mm. They are relatively light-duty components. They were formerly widely used for such tasks as fixing brake linings to brake shoes (adhesive bonding is now used for this). Their main advantage is the ease with which these rivets can be "set" or secured during assembly. Most hollow rivets have a head formed on one end, as seen in the examples in Fig 2-45, so that only one end needs to be "set" during assembly. These rivets are available in various metals, including aluminium, brass, steel and stainless steel.

### 3.2 Rivet materials

Hot rivets are almost invariably made from steel, generally low-carbon, although medium carbon steel can be used where higher strength is required.

Rivets intended for cold working must have good ductility. They may be made from low-carbon steel, aluminium, copper or brass. Special applications may use such materials as stainless steel, or monel metal (a corrosion-resistant nickel-copper alloy).

### 3.3 Pop riveting



**Figure 2-46:** *Top left:* Further examples of available rivets, including some solid rivets.

<http://catalogs.indiamart.com/products/blind-rivet.html?gclid=CPTuuOr8kKcCFQHVbgod-zX1bg>

*Top centre:* Three examples of pop rivets of different diameter but similar **GRIP LENGTH**, i.e. the thickness of material the rivet can effectively secure.

<http://en.wikipedia.org/wiki/File:Blindnieten.JPG>

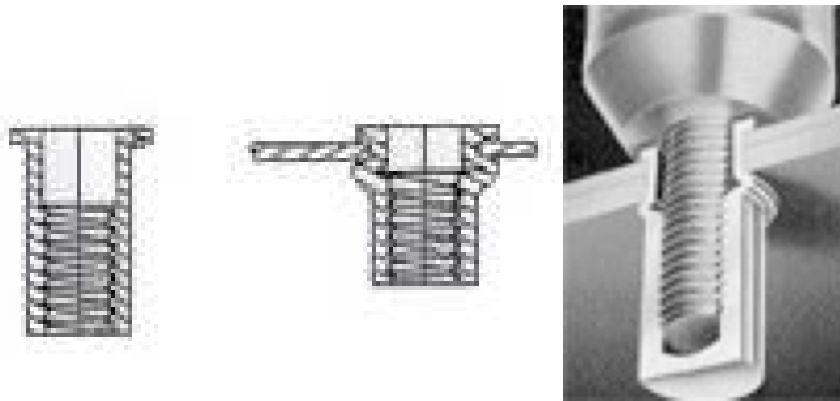
*Top right:* A pop rivet after being “set” by pulling through and breaking off the mandrel. [http://www.bayrivet.com/open\\_end\\_pop\\_rivets.htm](http://www.bayrivet.com/open_end_pop_rivets.htm)

*Bottom left:* Examples of some available heads on pop rivets. *Bottom right:* A further illustration of the rivet after **SETTING**. Again, the **MANDREL** has been broken off to leave a flush-fitting joint.

Pop riveting is a special application of hollow rivets which has been developed primarily for fixing sheet metal. The method is especially valuable because it requires access to only one side of the installation and pop rivets are often referred

to as **BLIND RIVETS**. The end of the pop rivet is expanded by pulling a ball-ended rod through the hollow centre of the rivet. At a pre-determined tensile force, the rod breaks off, leaving the ball in the rivet and the face of the joint smooth and almost flush with the surface.

#### FOR KEEN STUDENTS



**Figure 2-47:** This figure shows the arrangement of a RIVNUT, effectively a nut which can be rivetted into place. It requires access to only one side and produces a reasonably strong thread for a setscrew or bolt. The rivnut is inserted through a neat-fitting hole, then deformed in a manner similar to setting a pop rivet, using the threaded setting tool shown in the right-hand diagram, after which the screwed setting tool is screwed out, leaving the nut ready for use. Rivnuts are usually made from aluminium, so have limited strength. <http://www.rivetnuttool.com/>

There are numerous alternatives to rivnuts to achieve a strong threaded fastener in sheet metal components. Ask Google for “weld nuts” and see, for example: <http://www.fastenersunlimited.com/weld.htm#tab>, and <http://www.avonstainlessfasteners.co.uk/products17.htm>



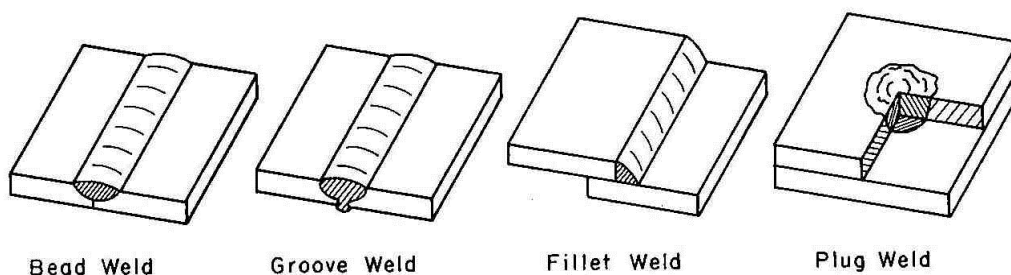
### 3.3 Welds

#### 3.3.1 Fusion welds

Welds are defined as joints between two or more components of similar material, formed by fusion (melting) of the parent (i.e. component) material. Weld filler material of similar composition is normally provided to fill up any spaces in the joint.

Welding may be carried out by a number of different processes, of which **OXY-ACETYLENE WELDING** and some version of **ELECTRIC-ARC WELDING** are the most common. In general, the welding process melts a filler rod or wire in order to provide material to form the joint. Sufficient heat must be generated to melt the surfaces of the parent metal in order to achieve fusion and hence complete bonding of the surfaces with the filler material. It follows that there are limitations on the minimum size of weld which can be used in any given configuration, as well as on the maximum size of components which can be welded.

**OXY-ACETYLENE WELDING** uses a flame created by mixing oxygen and acetylene in a pressurised jet to create a very hot flame. **ELECTRIC-ARC WELDING** generates heat by creating a very high current electric arc between an electrode and the parent metal. In general, electric-arc welding needs some method of protecting the molten weld material from oxidation. This is commonly done in the **METAL INERT GAS (MIG)** process in which the metal filler rod is surrounded by a layer of inert gas. In the tungsten inert gas (**TIG**) process, the arc is created by the tungsten electrode, which is surrounded by inert gas, but the tungsten does not melt to fill the joint.

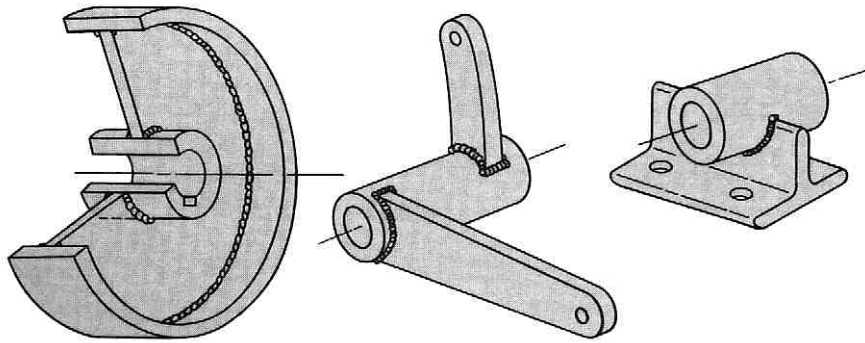


**Figure 2-48:** The basic types of fusion welds.

Reproduced from E.P. DeGarmo, *Materials & Processes in Manufacturing*, 5th Ed., Macmillan.

Figure 2-48 illustrates the most common types of weld in engineering practice. Each type may be created either by oxy-acetylene or by electric-arc welding. In butt-welds (i.e. the first two examples in Fig. 2-48) two pieces of material are joined end to end or edge to edge. In fillet welds, the two pieces to be joined may be overlapped, as shown in Fig. 2-48. Alternatively, the two pieces may be at 90° to

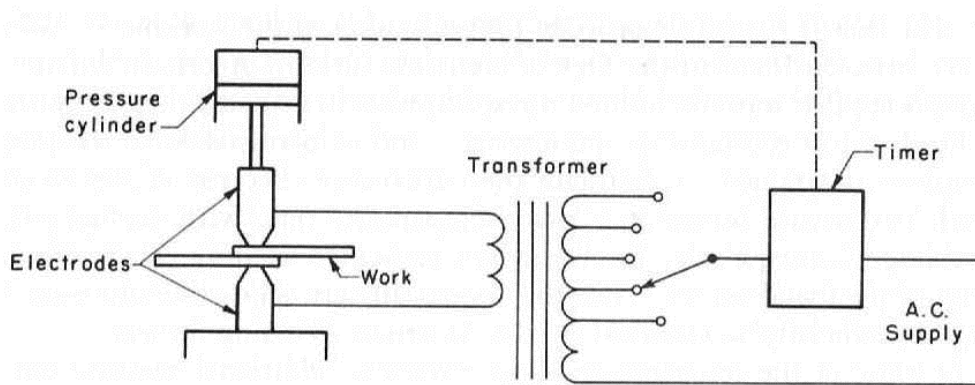
each other. The shape of the weld is similar in each case. The plug weld is less commonly used and is made by drilling a hole through one of the members to be joined, then filling the hole with weld material, ensuring that bonding occurs with the second component.



**Figure 2-49:** An illustration of some **FABRICATED COMPONENTS**, in which components similar in shape to castings or forgings can be made by welding together various structural shapes such as flats, pipes, rounds, T-sections, etc. From Juvinall, R C, *Fundamentals of Machine Component Design*, Wiley, 1983, page 337.

### 3.3.2 Spot welds

Spot welds are another important fastening method, often used in sheet-metal industries. They are widely used in the production of car bodies, for example.



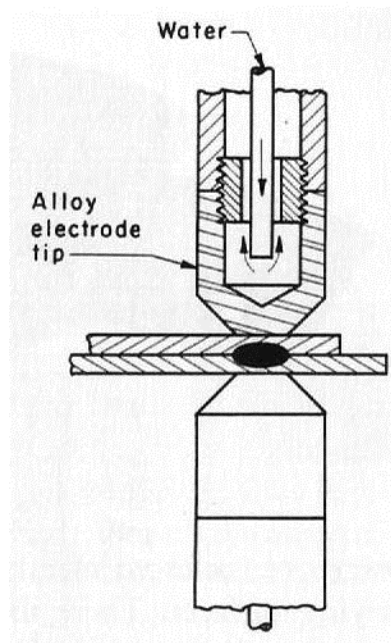
**Figure 2-50:** Basic arrangement for **SPOT WELDING**, also known as **RESISTANCE WELDING**.

Reproduced from E.P. DeGarmo, *Materials & Processes in Manufacturing*, 5th Ed., Macmillan, page 860.

The workpiece in Fig 2-50 comprises two metal sheets which are to be **SPOT-WELDED** together by passing a large electrical current between two **ELECTRODES**. The electrodes are mounted in the apparatus in such a way that they can clamp

together the two metal sheets which comprise the workpiece. In the machine illustrated, clamping is achieved by means of air pressure in a pressure cylinder. An AC power supply is passed through a transformer, reducing its voltage and increasing its amperage and the high amperage current is connected to the two electrodes. With the large electrical current passing through a small area contacted by the electrodes, the resistance of the workpiece causes heating, sufficient to melt a small area of the workpiece and weld the two sheets together. A built-in timer is set to disconnect the current after sufficient time to form the weld.

Spot welds are readily recognised by the slight indentation of the surfaces caused by deflection of the sheet metal under the electrodes. In the smaller sizes, electrodes are usually round but in larger sizes (e.g.. as used to spot weld steel automotive wheel rims to wheel centres and other heavy-duty applications) square or rectangular electrodes up to about 16 mm square (with slightly rounded corners) may be used. Naturally, very large currents are required with large electrodes.



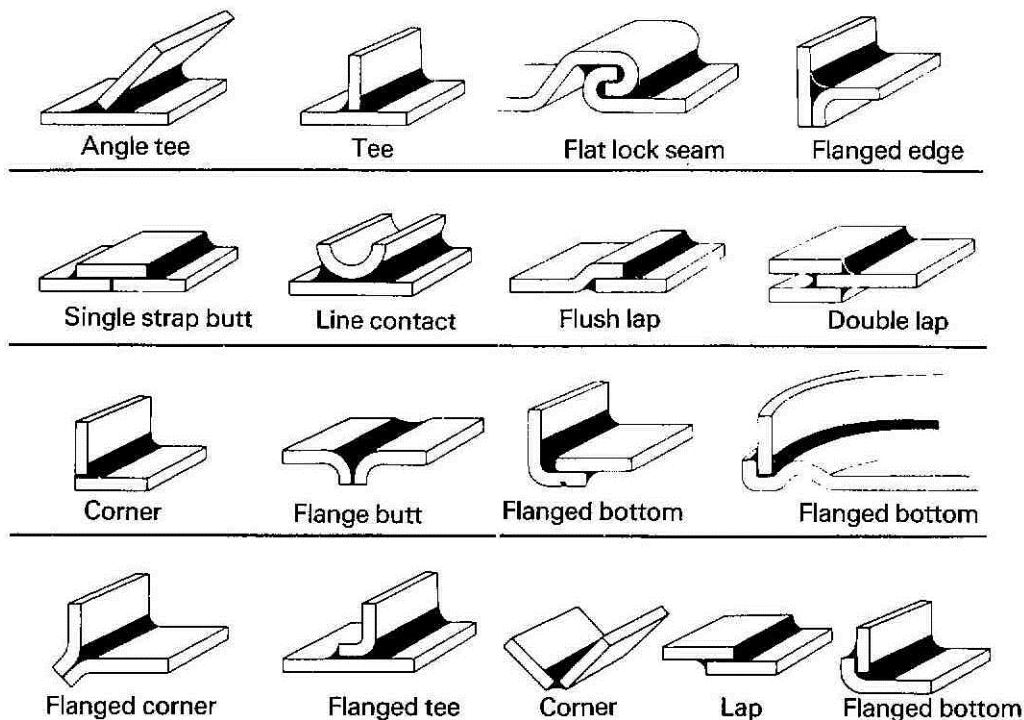
**Figure 2-51:** A more detailed view of the arrangement of the electrodes and the work in spot welding. Water is required to cool the electrodes. The black area on the workpiece indicates the relative size and shape of the welded material.

Reproduced from E.P. DeGarmo, *Materials & Processes in Manufacturing*, 5th Ed., Macmillan, page 861.

### 3.3.3 Brazing

Brazing is defined as a process in which two or more components are joined by molten metal, where the molten metal is of dissimilar composition and melts at a lower temperature than the components to be joined. In the brazing process, as distinct from welding, the surfaces of the parent metal (i.e. the components) do not melt.

Fig. 2-52 illustrates some typical brazed joints. With brazing, it is important to design the joint with a large enough area to achieve the required strength.



**Figure 2-52:** Typical joint designs for brazing.

Reproduced from H.W. Yankee, *Manufacturing Processes*, 1979, Prentice-Hall, page 718.

Small brazing jobs may be carried out using an oxy-acetylene torch. Larger production runs often use the process of **HYDROGEN BRAZING**, in which large batches of components have their joints prepared before being passed on a conveyor through a furnace with a reducing atmosphere (excess of hydrogen) to melt the copper-based brazing material and form the joint.

The filler material used in brazing may be one of several copper alloys or a silver alloy. Brazing with a silver alloy is sometimes referred to as **SILVER SOLDERING**.

### 3.3.4 Soft soldering

At the low-temperature, low-strength end of the scale, lead-tin alloys known as soft solders provide very useful joints for electrical wires and similar applications. Hand soldering is usually done with a soldering iron, although using a small oxy-acetylene flame can be a useful method on heavier parts such as water pipes.



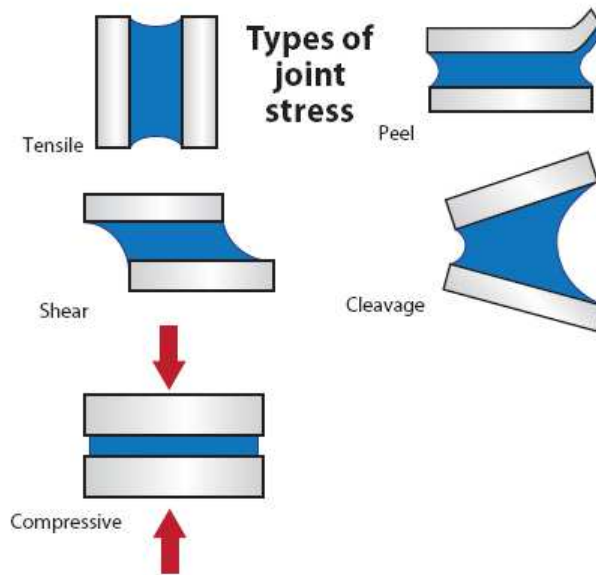
**Figure 2-53:** An example of a proprietary soldered fitting known as a Yorkshire fitting. Copper pipes have already been soldered into two of the openings of the T-piece on the right. A thin ring of solder is visible in the upright opening. When a clean and flux-covered copper pipe is inserted into the upright opening and the T-piece heated, the solder melts, spreads over the whole contact area, and forms a strong pressure-tight joint. <http://www.pegler.com/EN/Products/Yorkshire/General>

### 3.4 Adhesive joints

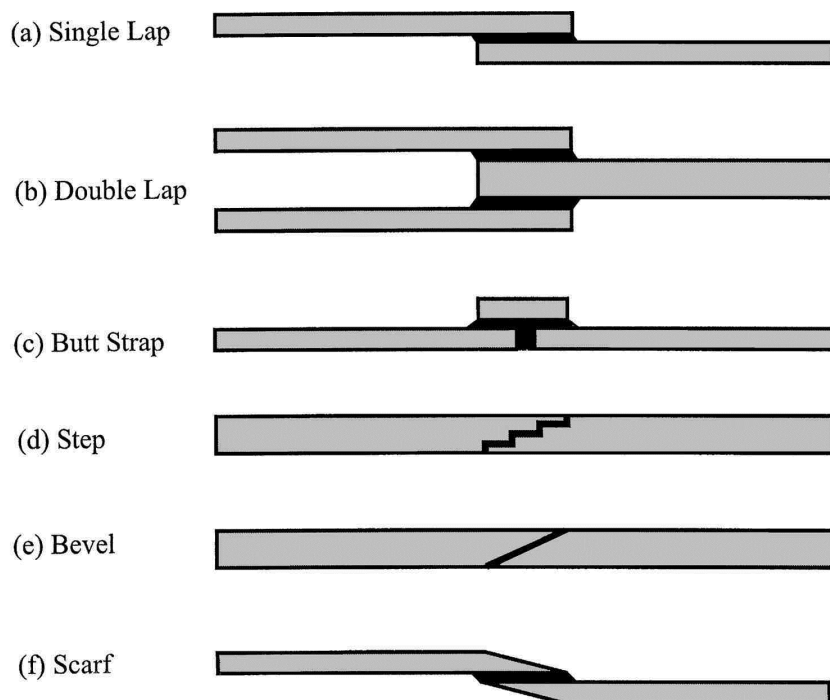
The use of adhesives in engineering applications is a rapidly burgeoning area, and one with which young engineers will need to become familiar. In these notes, however, only a few general remarks can be made.

Adhesives are currently used in structural areas such as the construction and fixing of aircraft panels. In such areas, stresses are generally well distributed over the whole panel and can thereby be kept reasonably low. Adhesives are generally not suitable for applications where loads, forces and torques are highly concentrated. However, windscreens and rear windows of many motor vehicles are now secured by strong adhesives around their edges and add significantly to the structural strength and stiffness of the vehicle.

It is generally considered desirable to design adhesive joints with generous bonded areas. Adhesive joints usually perform well if they are designed to be loaded in shear. Compressive loading is also good design. Uniformly distributed tension is acceptable (if it can be achieved) but loading of the types described as peel and cleavage in Fig. 2-52 are to be avoided. Fig 2-53 illustrates methods of reducing the shear stress on adhesive joints by increasing the area of adhesive.



**Figure 2-54:** Types of stress resulting from the application of different directions of loading on adhesive-bonded joints. Blue areas in the diagrams typically represent rubber or polymer which has been adhesively bonded to metal plates. It is good practice to avoid loading which peaks at one edge of the joint, e.g. peel or cleavage, as shown on the right. <http://images.google.com/images>



**Figure 2-55:** Design of adhesive joints loaded in shear in which the load-carrying capacity of the joint has been increased by increasing the area of adhesive.

<http://images.google.com/images>