FASTENERS

Fasteners are everywhere. Screw fasteners are easily removed and adjusted. Other fasteners include pins, keyways and circlips.

Screw Fasteners

Screw fasteners are based on metric or imperial (inch) thread forms. The size of the thread is the nominal (rounded-off) outside diameter. For example M12 means Metric with 12mm nominal outside diameter.

Screw fasteners have the following advantages;
+ Removable
+ Simple to install with common tools
+ Relatively cheap (because they are so common)

Disadvantages;
- Critical applications must not loosen (friction nuts, lock washers, torque, Loctite, deformed thread, wiring, pinning)
- Can be damaged during installation by over-tightening. (requires Torque Wrench)
- Requires a hole (not potentially as strong as welding/brazing/gluing in some applications)
- Can be bulky in some applications (e.g. sheet metal)

What is the difference between a SCREW and a BOLT? (Link)
Good question! A Bolt is designed to fit with a nut. A Screw is designed to fit into a tapped hole. Most screw fasteners can do both, except for a few head types that cannot be torqued - like Round Head, Plow Bolt etc. These are always called bolts.

The term Bolt is also used when the fastener is DESIGNED to be used with a nut (like a structural bolt for example), even though it can act as a screw.
A **Set Screw** is used to secure an object within another object. It is generally fully threaded. A **grub screw** (or blind screw) has no head, so must be torqued by an internal Hex, Allen, slot, Torx, star or Phillips or Straight driver. The common use of a set screw is locking a hub onto a shaft, usually against a flat on the shaft or a key.

A selection of various screw fastener heads:
### Classification by Fastener Type

- **Set Screw**: X
- **Grub Screw**: V, W
- **Stud**: Z

### Classification by Driver Type

- **Straight slotted Screwdriver**: A, D, G, H, K, O, V
- **Philips Head Screwdriver**: B, E, I, L, P
- **Posidrive Head Screwdriver**: C, F, J, M
- **Allen key (Socket head)**: S, T, U, W
- **Hex Head (Hexagonal spanner or socket driver)**: N, O, P, Q, R
- **Square Head**: (Spanner) X, Y
- **Wing**: (Hand tightened) AA / No head: (Stud) Z, (Dome) CC / Eye: (Attach cable) BB

**Driver type Summary** ([Wikipedia](http://www.learneasy.info/MDME/MEMmods/MEM30009A/Fasteners/Fasteners))
Classification by Head Style

- Countersunk: A, B, C, S
- Raised Countersunk: D, E, F
- Pan Head: G, H, I, J
- Cheese Head: K, L, M
- Hex Head: N, O, P, Q, R
- Flanged: Q, R
- Cap Screw: U
- Dome Head: CC / Wing: AA / Eye: BB

Head Style Summary ([Wikipedia](http://www.learney.info/MDME/MEMmods/MEM30009A/Fasteners/Fasteners.html))

(a) pan, (b) button, (c) round, (d) truss, (e) countersunk, (f) oval

Screw Fastener materials

- Steel (Mild)
- High Tensile Steel (Bolt grades 6.8, 8.8, 10.9, 12.9 etc)
- Stainless Steel (most type available)
- Brass (limited range)
- Aluminium/Titanium (rare - special use)

Plating of Steel Fasteners

- None (Will rust except in very dry environment like air conditioning)
- Zinc electroplated (Thin coating with limited corrosion resistance but good finish). Zinc plated steel is almost always a bright, silver colored finish. Chromate conversion coatings are applied for increased corrosion resistance. The chromate conversion coatings are available in blue, yellow (gold), olive drab, black etc. Chromate conversion is also called *passivated*.
- Hot-dip galvanized (larger, coarse threads typically 10mm and above, High corrosion resistance)
- Many other metal platings - chrome, nickel, copper, etc
- Black (oil) finish (Usually high tensile bolts. Slight rust prevention - dry or oily environment only)

Fastener Head Proportions (Boundy)

These are typical proportions of screw fasteners, but you may need to refer to manufacturer's data for exact dimensions.
LG - Grip Length: The depth from surface to bottom of bolt.

**Thread Size vs Spanner (wrench) Size** ([Wikipedia](http://www.learneasy.info/MDME/EMMmods/EM3009A/Fasteners/Fas...))

<table>
<thead>
<tr>
<th>ISO metric thread</th>
<th>M1.6</th>
<th>M2</th>
<th>M2.5</th>
<th>M3</th>
<th>M4</th>
<th>M5</th>
<th>M6</th>
<th>M8</th>
<th>M10</th>
<th>M12</th>
<th>M16</th>
<th>M20</th>
<th>M24</th>
<th>M30</th>
<th>M36</th>
<th>M42</th>
<th>M48</th>
<th>M56</th>
<th>M64</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrench size (mm)</td>
<td>3.2</td>
<td>4</td>
<td>5</td>
<td>5.5</td>
<td>7</td>
<td>8</td>
<td>10</td>
<td>13</td>
<td>17</td>
<td>19</td>
<td>24</td>
<td>30</td>
<td>36</td>
<td>46</td>
<td>55</td>
<td>65</td>
<td>75</td>
<td>85</td>
<td>95</td>
</tr>
</tbody>
</table>

In addition, the following non-preferred intermediate sizes are specified:
<table>
<thead>
<tr>
<th>ISO metric thread</th>
<th>M7</th>
<th>M14</th>
<th>M18</th>
<th>M22</th>
<th>M27</th>
<th>M33</th>
<th>M39</th>
<th>M45</th>
<th>M52</th>
<th>M60</th>
<th>M68</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrench size (mm)</td>
<td>11</td>
<td>22</td>
<td>27</td>
<td>32</td>
<td>41</td>
<td>50</td>
<td>60</td>
<td>70</td>
<td>80</td>
<td>90</td>
<td>100</td>
</tr>
</tbody>
</table>

**Specifying a Screw Fastener**

Screw fasteners are usually specified in a certain sequence;
M | Thread diameter | x | pitch (optional) | x | length LG | Driver type | Head type | Plating | Material

Example:
*M12 x 50 long Socket Head Cap Screw Zinc Plate*
In this case, no pitch is specified so the standard M12 pitch is used. When material is not specified steel is assumed.

**Metric Thread Profile**

Metric thread profile (Wikipedia). Nut is on the top, bolt on the bottom.

Metric threads form a 60° triangle, so the height $H = P \times \sin(60°) = 0.866P$.

The root (bottom) of the thread is not a sharp corner because it would be difficult to machine and also make the bolt prone to crack, especially in fatigue. Instead, it is rounded off by 1/4 H. The same happens inside the nut, although a little sharper this time, the top of the bolt threads is cut off by only H/8. This leaves 5/8H of actual contact between the bolt and the nut.

In the standard metric threads, the pitch P is a standard proportion of the diameter rounded to the nearest mm (or convenient fraction of a mm). Nominal diameter is the rounded-off diameter of the outside of the bolt thread.
Standard metric thread sizes (Wikipedia).

**Fine vs Coarse Threads**

Fine threads have a smaller pitch for the same diameter. This gives a larger cross-section for the bolt - which means it is stronger. They are also better in fatigue because there is a less sudden change in diameter. Fine threads give a higher clamping force for the same tightening torque, which has the added benefit of not coming apart as easily under vibration. The main disadvantage of fine threads is the need for higher accuracy, which means they are more sensitive to coatings (they need to be thin), and dirt (easier to get jammed if rusty, dirty etc).

**Rolled vs Cut (Machined) Threads**
SUBSTANTIAL MATERIAL SAVINGS
When a thread is produced by rolling, material savings are inevitable. A rolled thread requires a smaller blank. The finished part's major thread diameter is produced by the outward flow of displaced material. On the other hand, a cut thread's blank diameter and thread diameter are equal to one another. Thread rolling produces no waste material. The table below clearly shows the tremendous savings inherent in the thread rolling process.

<table>
<thead>
<tr>
<th>Thread Size</th>
<th>Material Savings</th>
<th>Thread Size</th>
<th>Material Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 - 32</td>
<td>24%</td>
<td>3/4 - 10</td>
<td>16%</td>
</tr>
<tr>
<td>1/4 - 20</td>
<td>25%</td>
<td>1 - 8</td>
<td>18%</td>
</tr>
<tr>
<td>3/8 - 16</td>
<td>27%</td>
<td>1 1/4 - 7</td>
<td>16%</td>
</tr>
<tr>
<td>1/2 - 13</td>
<td>19%</td>
<td>11/2 - 6</td>
<td>16%</td>
</tr>
<tr>
<td>5/8 - 11</td>
<td>19%</td>
<td>2-41/2</td>
<td>15%</td>
</tr>
</tbody>
</table>

GREATER ACCURACY & UNIFORMITY
The thread rolling dies of today are ground and polished to exacting specifications. So extreme accuracy is always a reality. In fact, maintaining a pitch diameter tolerance of .001" can be held. But the major advantage thread rolling has over all other types of thread production, is the ability to remain extremely accurate over very long production runs. The key is in the die. A thread rolling die does not erode over time because the contact point is not concentrated on a sharp cutting edge, but is instead distributed over a broad surface. Also, the thread rolling process itself is relatively friction free, so adhesion does not cause problems either. Therefore, if each of the blank's dimensions are uniform, the first part produced will be the same as the one thousandth part produced.

FASTER
No other thread producing method can touch rolling in the speed department. Whether a production run involves small or large quantities, the labor savings are tremendous.

OTHER COST-SAVING FEATURES
- Thread Rolling Dies do not require sharpening. No down time for sharpening or resetting.
- Thread Rolling's uniformity saves money on inspection labor.
- Rolling can be performed on the collect end behind a part's shoulder, often saving a secondary threading operation.
There is a hardened rolling die on each side of the job (which is the bolt being rolled). The rolls apply a large pressure against the workpiece which deforms (forges) the thread onto the job. The rolled thread ends up larger in diameter than the shank of the bolt, which is usually a good thing for fatigue. A rolled thread is stronger than machined threads because of grainflow, making it more difficult to "strip the thread".

Hole Detailing

Countersink (for a countersink head), Counterbore (for a cap head) and Spotface (for hex head).
Washers

A selection of washers:
The role of a washer can be:

- Protection: Prevent scoring of the surface by the nut or bolt head, or spread the load over a wider area
- Locking: Prevent the nut/bolt from coming loose (Helical/Spring/Split washer, star washer)
- Insulation: (for thermal, electrical, corrosion reasons)
- Sealing: Prevent leakage (e.g. Copper washer used for sump plug)
- Alignment: Tapered washer to give a level surface on an angled face.

Nuts

These lock the clamped material against the bolt head. In applications where vibration or rotation may work a nut loose, various locking mechanisms may be employed: Adhesives (Loctite), split pins or lockwire, nylon inserts, or slightly oval-shaped threads.

L to R: Wing, hex, hex flange, and slab weld nuts.

L to R: Slotted, square, T, cap (or acorn), nylon locking, and castellated nuts.
Pins

Pins are mostly used to locate two objects together.

**Dowel pins** are the most accurate, machined to tight tolerances and pressed or free fitting into reamed holes. In a bolted joint, the play would be typically 0.2mm for a 10mm (3/8") bolt. When dowels are used, the accuracy would be typically 0.02mm. Oftern used when precise mating alignment is required, such as in differential gear casings, engines, injection moulding tools, press tools etc.

![Dowel Pins](image)

**Spring Pin (or Roll Pin)**
The same idea as dowel pins, but do not require accurate holes or pins because the pin 'squeezes' into the hole. The friction is reliable and easy to extract but more as a way of holding parts together than accurate location.

![Spring pin](image)

**Split Pin (or Cotter Pin)**
Next level down from the Roll Pin in terms of accuracy. No real accuracy is needed on the hole and it can even tolerate an incorrect pin diameter to a limited extent. The "R" pin is a similar concept but is more readily removed and re-inserted multiple times.

![Split Pins and "R" pin](image)
Keys and Keyways

Parallel keys are the most widely used. They are sized according to the shaft diameter (square keys for smaller shafts, rectangular for shaft diameters over 170 mm. Set screws may be used to lock the mating parts into place so they do not move. The keyway is a longitudinal slot in both the shaft and mating hub.

Woodruff keys (half-moon keys) are semicircular shaped keys that, when installed, leave a protruding tab. The keyway in the shaft is a semi-circular pocket and the mating part has a longitudinal slot. They are used to improve the concentricity of the shaft and the mating part, which is critical for high speed operations. The main advantage of the Woodruff key is that avoids the milling of a keyway near shaft shoulders, which already have stress concentrations. Common applications include machine tools, automotive applications, snowblowers and marine propellers. Can also be used in combination with a tapered (conical) fit.
A Woodruff key and keyway

Gear G is held on shaft S by Woodruff key N

**Tapered keys** use a wedge action to fit the key. Some taper keys have a gib, or tab, for easier removal during disassembly. Excessive wedge force and/or a loose fitting shaft can push the hub off-centre. Gib head key is shown below.

Scotch key is simply a hole drilled axially into the part and the shaft, so that a round key can be used. It works, but is difficult to match a replacement part. Circular cross section gives low stress concentration.

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### Circlips

Circlips, (snap ring, retaining ring). These clips prevent axial movement on a shaft, but normally with some play. Common for smaller equipment - rollers, bearings etc.

![Internal Circlip](image1)

![External and internal circlips in the standard design.](image2)

![E clip](image3)

E clip can be pushed on from the side of the shaft without the need to stretch over the end of the shaft. Less secure.
Push-on clip. No groove required.

Rivets

Solid rivets were commonly used from the 1800's for all sorts of steelwork (bridges, ships, tanks and pressure vessels, truck chassis, machinery) until being mostly superceded by welding in the mid 1900's.

A worker swages one of 6 million steel rivets used in the construction of Sydney Harbour Bridge.

Rivets are still used in aircraft - and can be used in combination with adhesives which give higher strength and ensure a sealed joint.


Solid aluminium rivets used in aircraft.
Rivets in aircraft body

Countersunk head of flush aircraft rivet showing inner swaging dimensions.

Today, the most common type of rivet is the Pop-rivet - where the swaging is done from the outside by a self-breaking pin through the centre of the (hollow) rivet. Solid rivets are more difficult to fit but are stronger and more reliably sealed than the hollow pop-rivet.

http://www.technologystudent.com/joints/popriv1.htm

Pop rivet before inserting into hole
Pop-rivet after pulling and breaking (popping) the pin, forming a clamping fastener between the 2 sheets.

Pop rivets are limited to light duty, usually thin sheet metal and some (non-brittle) plastics. They are often aluminium (soft), but can also be made from steel, stainless steel and brasses.

Pop rivets being used to join the thin steel (or aluminium) guttering.

VIDEO (From college library)

<table>
<thead>
<tr>
<th>Joining Metals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheppard, Phil. Bendigo, Vic. : Classroom Video, c2006. DVD (29 min.).</td>
</tr>
<tr>
<td>An introduction to the methods of joining metals, including riveting and fusion and non-fusion methods of welding.</td>
</tr>
<tr>
<td>Mt Druitt College Library: DVD 671.5/JOIN</td>
</tr>
<tr>
<td>Joining Metals Notes (pdf)</td>
</tr>
</tbody>
</table>
Recommended Viewing: The first 20% only. This first section describes rivets, bolts, pop-rivets. The rest of the video is about welding, which is not relevant here.

Laboratory Demonstration

Questions:

Relevant pages in MDME

- Boundy Keyways.pdf

Links

- Google search: "screw fasteners"
- Distinguishing Bolts from Screws (US)
- Pop rivets http://www.technologystudent.com/joints/popriv1.htm

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