Design and Manufacture

OLHS Technical Department

Metal

Knowledge and Understanding Book

Metals

All metals in use today are either PURE METALS or ALLOYS. Copper, iron, tin, lead, gold and silver are all examples of PURE METALS which have been mined from the Earth and extracted from the ore using a process called SMELTING.

An ALLOY is a mixture of pure metals or a metal with a substance such as carbon added; examples of alloys are:- **Steel** (Iron & Carbon), **Duralumin** (Aluminium & Copper), **Brass** (Copper & Zinc) & **Bronze** (Copper & Tin).

Metals are usually classified into two main groups; FERROUS metals and NON-FERROUS metals.

Ferrous Metals

This category of metals contain iron and are usually magnetic; examples of such are Cast Iron, Mild Steel, High Carbon Steel, etc.

Non-Ferrous Metals

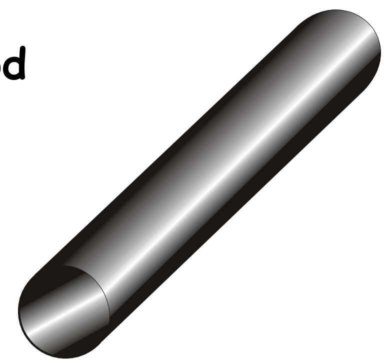
As the name implies (NON), this category of metal does not contain iron and is usually non-magnetic; examples are, Aluminium, Copper, Brass, Duralumin, Lead, Gold, Silver, etc.

Form of Supply

Most metals are available in a wide variety of shapes and sizes and are usually described by their cross-section. i.e. what they look like when they have been sawn through.

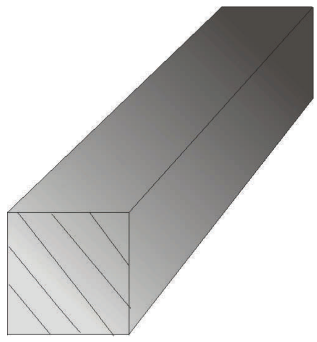
The following cross sections are typical examples of how metals are supplied to the school workshop.

Round Rod

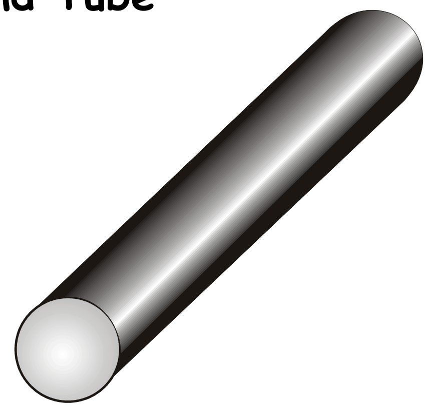


Sheet

Squares

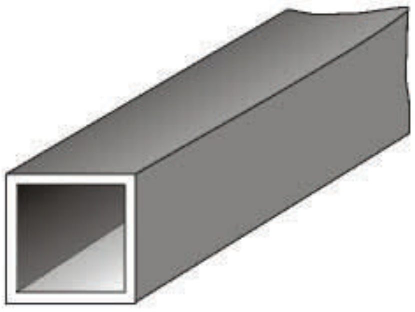


Round Tube

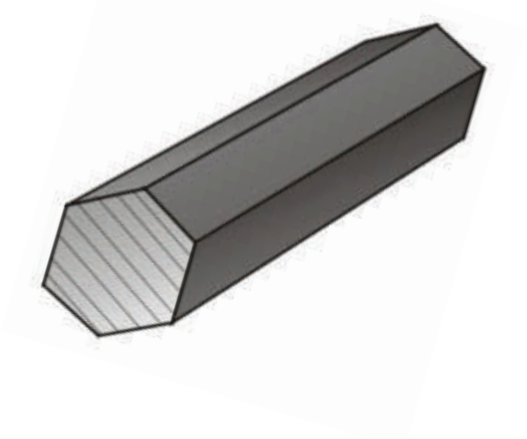


Flats

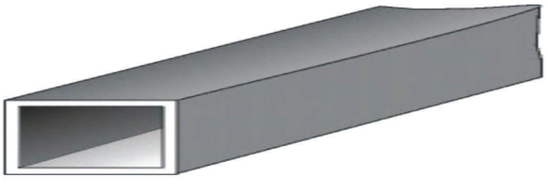
Square Tube



Hexagonal Bar



Rectangular Tube



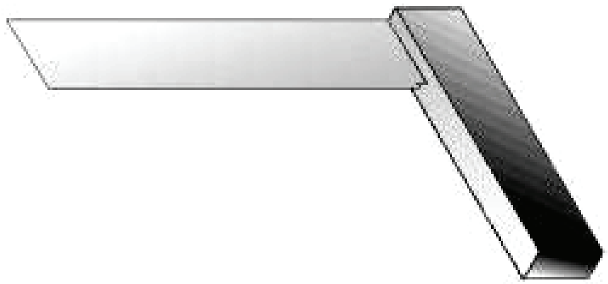
Octagonal Bar

Angle

Metal Working Tools

Marking Out Tools

Engineers Square

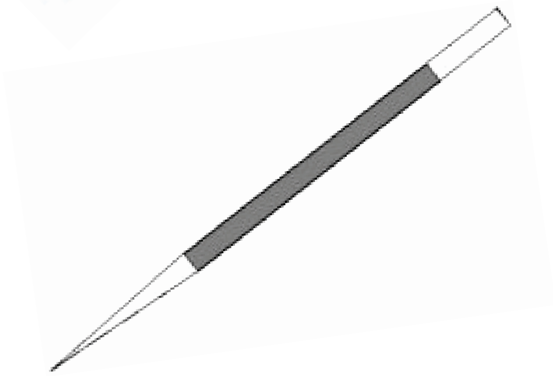


An Engineers Square is similar to the Try Square except it is smaller and made of metal. It is used to check that the edges of the plastic or metal are square or to scribe lines at **Right Angles** to an edge.

The Centre Punch

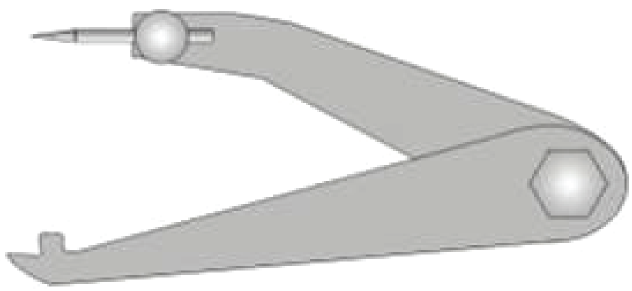
Before metal can be drilled with a twist drill the surface must be firstly punched using the Centre Punch. The reason for this is to ensure the drill does not slip on the surface.

Scriber



The scriber is a tool which is used to "SCRIBE" or mark lines on metal.

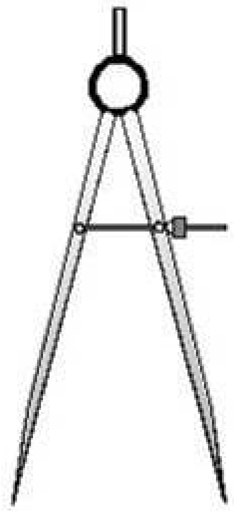
Odd Leg Callipers



These are used to mark out lines on metal **Parallel** to an edge.

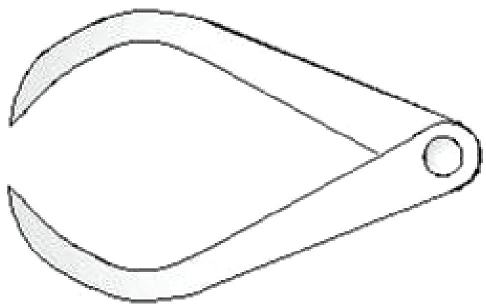
Spring Dividers

These are used to mark out circles and arcs and to step out equal lengths along a line.



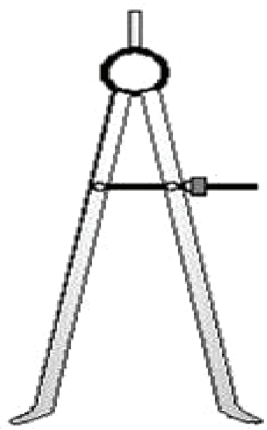
Outside Callipers

Outside callipers are used for testing the outside diameters of round bars and thicknesses of sheet metal where it is difficult to use a steel rule.



Inside Callipers

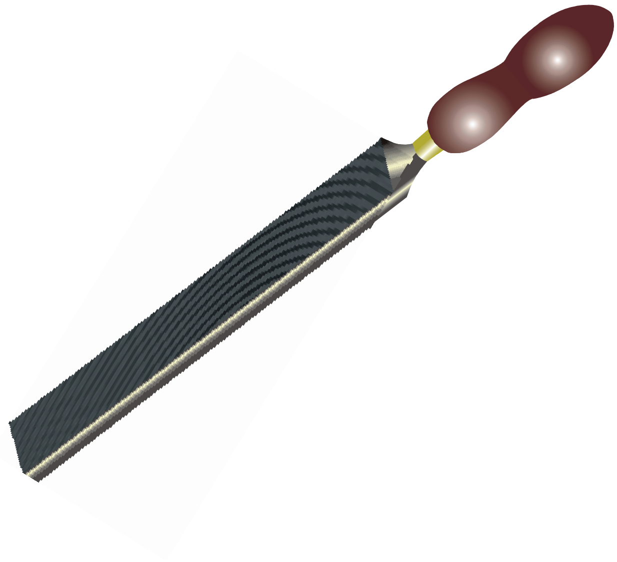
Inside callipers are used to test the diameters of holes or the distances between two surfaces where it would be difficult to use a steel rules



Files

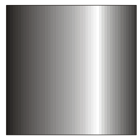
Files are used to shape metal.
They are available in a number of different shapes and degrees of roughness.

Files must not be used without a handle.

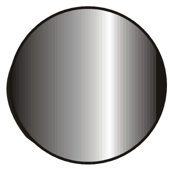


Sections of Files

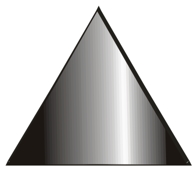
Square



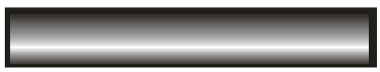
Round



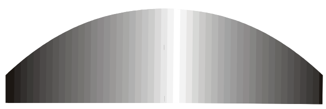
3 Square



Flat

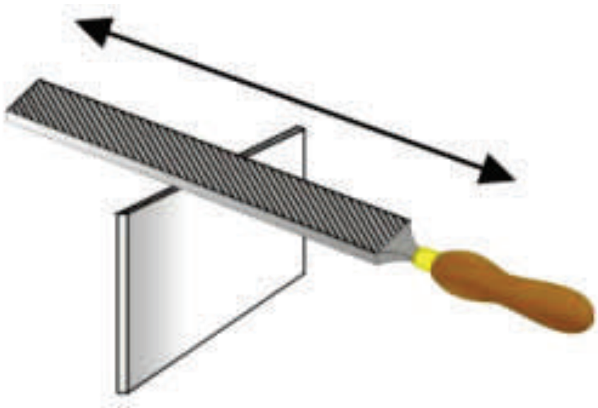


Half Round



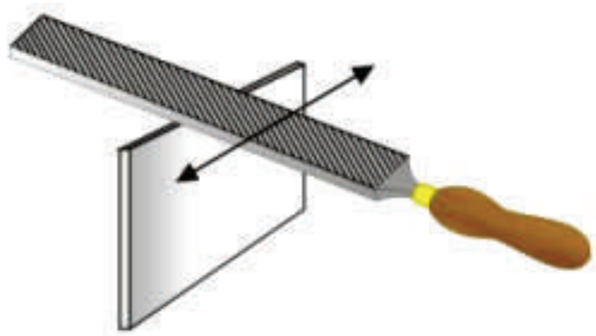
Cross filing

In this type of filing the file is moved across the work piece using the full length of the blade. This method of filing is used for removal of a lot of material with every stroke applied.



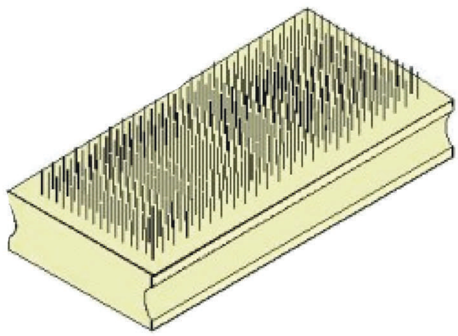
Draw filing

In this method of filing, the file is moved sideways along the work piece and is used to obtain a smooth finish after cross filing. This method does not remove much material.



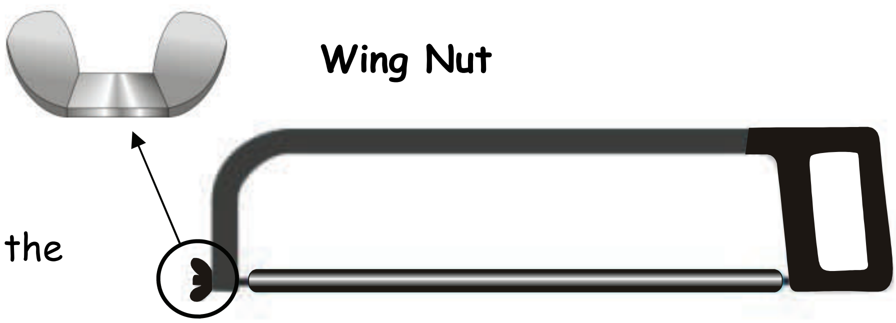
Cleaning the file

Small pieces of aluminium or plastic can be trapped in between the teeth of the file. This is called **PINNING**.
A **FILE CARD** can be used to clear the file of the excess material. The file card looks very similar to a wire brush except the teeth are very short.



Hacksaw

The hacksaw is used for general cutting of metal bar, tubes, etc. The blade is easily removed by slackening or tightening of the front wing nut.



Junior Hacksaw

This type of saw is also used for cutting metal but is used for light work or where a hacksaw is too clumsy.

Raw Hide Mallet

This mallet is used when it is important not to make any marks on the metal.

Ball Pein Hammer

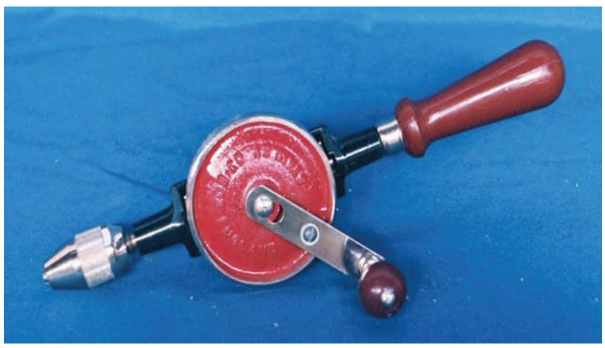
This is a general use hammer although the ball pein end of the hammer is used specifically to round the heads of the snap head rivet.

Portable Electric Drill

These drills are usually available in schools with a maximum chuck capacity of 13mm (i.e. can hold a drill diam. of 13mm maximum).

Hand Drill

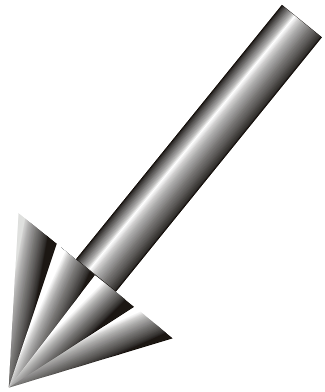
The hand drill or WHEEL BRACE is used to hold and turn twist drills up to 8mm in diameter. The chuck has three self centring jaws which securely grip the shank of the drill.



Drills

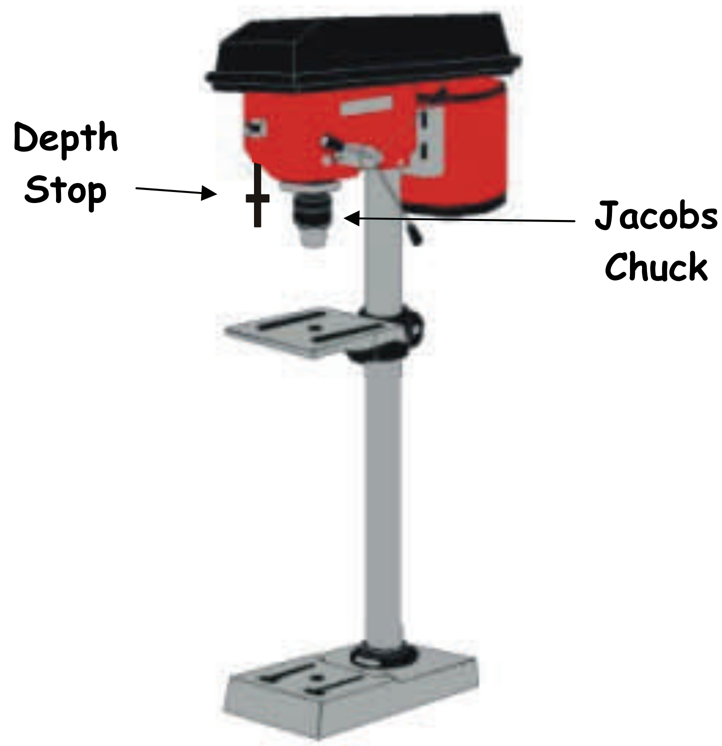
Drills are manufactured from high speed steel (H.S.S.) or carbon steel and are used for drilling circular holes in metal, plastic or wood. The most common type of drills used are the TWIST DRILLS. These drills have three basic parts, a point, a parallel body and a shank which can be either parallel or tapered.

A countersunk drill is used to countersink holes in wood, metal and plastics to allow the accommodation of a countersunk screw head. As can be seen from the sketch opposite the screw will head sit below the surface of the material.



The Pillar Drill

The pillar drill (or Vertical Drill) can either be bench mounted or floor mounted. The chuck (part which holds the twist drill) can hold drills up to 13mm in diameter. The adjustable table which holds the work piece can slide up or down and can be locked at a desirable height.



Safety Check

Before Drilling - ensure the drill is secure with the chuck key removed, eye protection on, guard in position and work piece securely held.

Standard Screw Threads

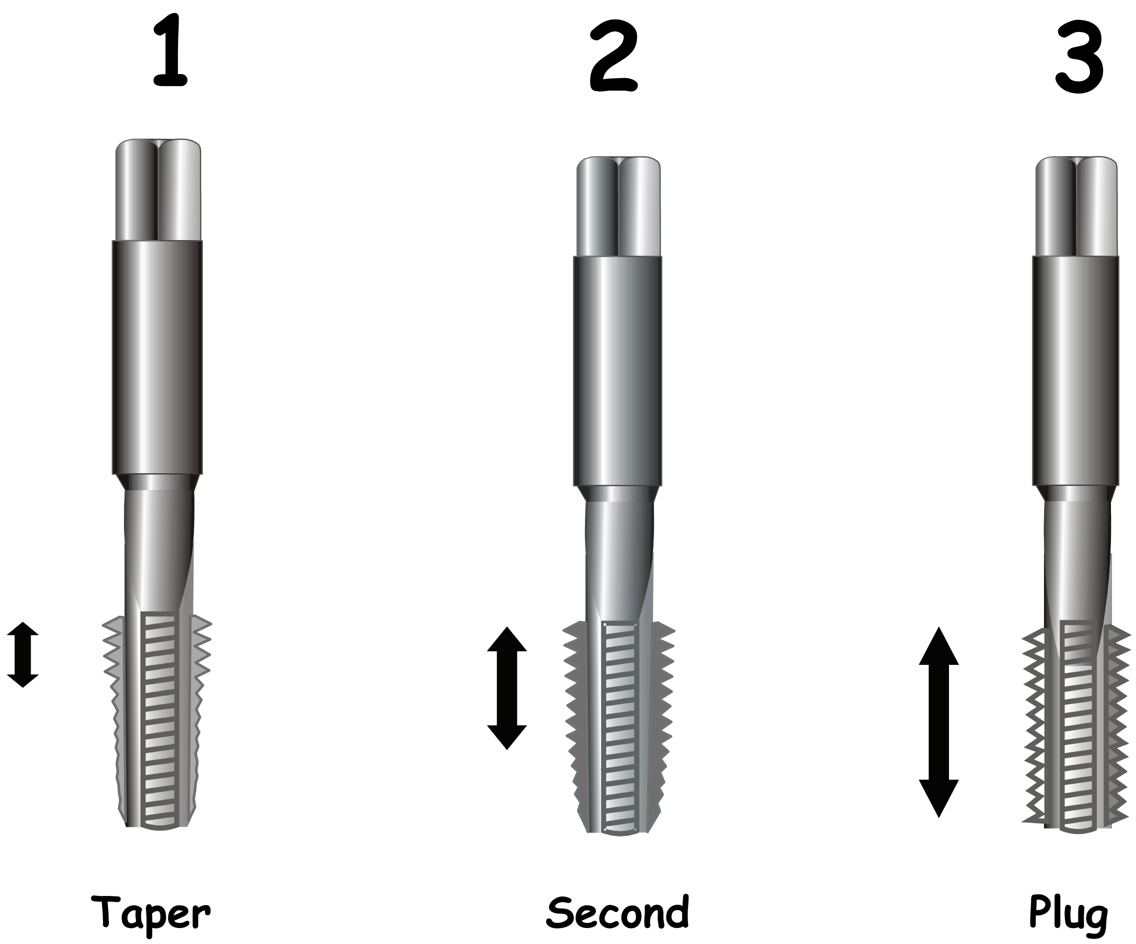
The screw thread is a very important detail in engineering. I is used to hold parts together. (e.g. bolt & nut) and to transmit power (e.g. vice screw).

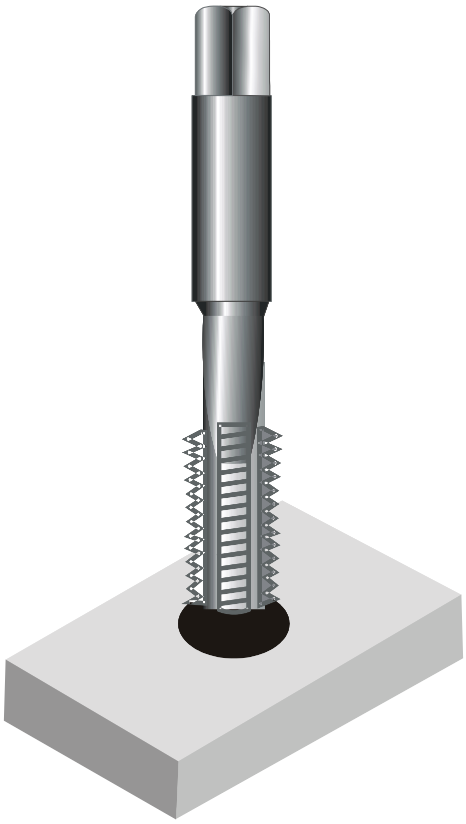
Screw Cutting

To achieve an internal screw thread, a hole has to be drilled first and then a tool called a TAP is used to cut a thread within the hole. TAPS are made from high speed steel (HSS). The top of the tap is square which enables the tap to be held securely in a TAP WRENCH, which can be seen below.

Taps are generally available in sets of three and are used in the following order:-

1. **Taper Tap**
2. **Second Tap**
3. **Plug Tap**





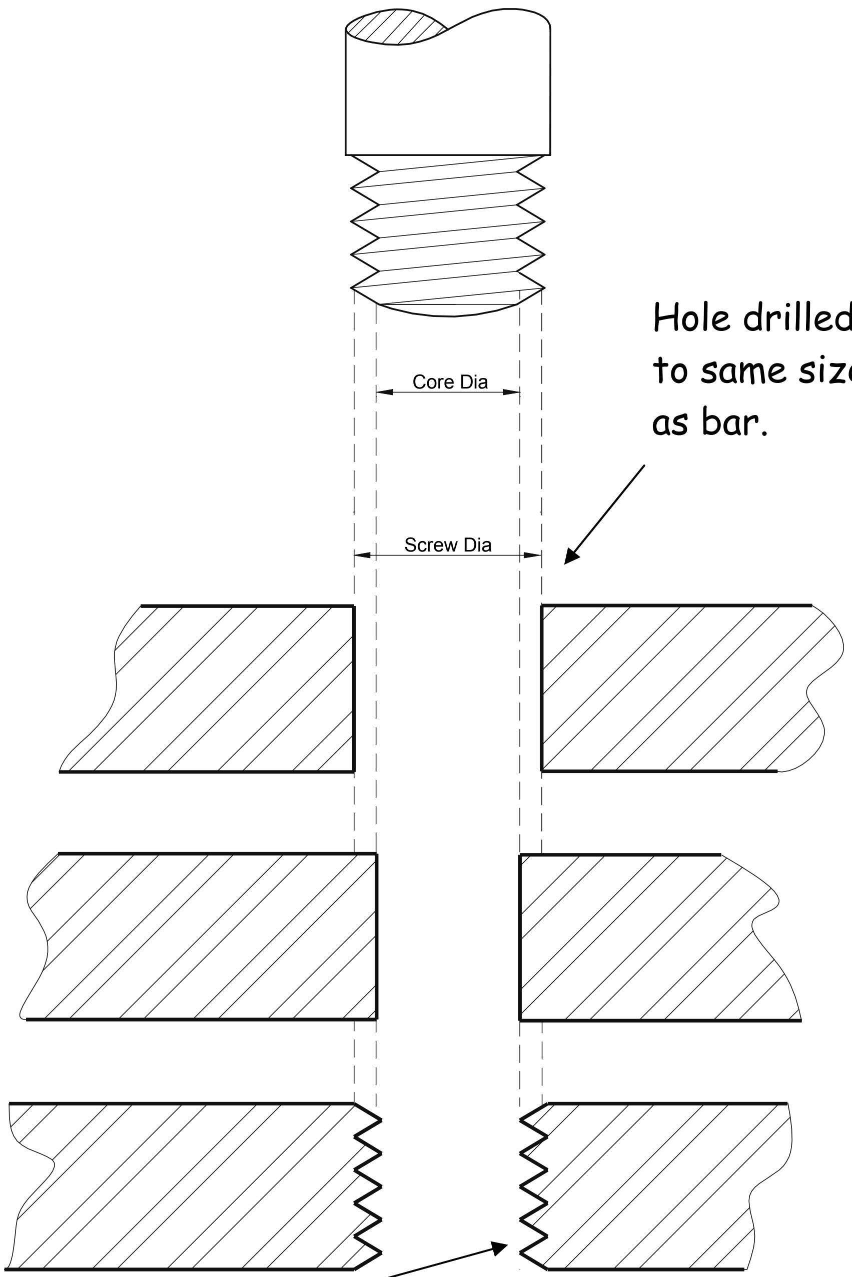
As has been mentioned on the previous page, taps are used in sequential order.

As can be seen in the taps above, the Taper tap has much smaller teeth at the bottom than the Second or the Plug taps. This allows the taper tap to get started by making a shallower thread cut. The taper cut is followed by the second tap which has slightly more teeth. Finally, the Plug tap is used which will make the full thread cut.

Remember to use the correct cutting lubricant

Internal Threading

When tapping a thread in an internal hole the actual diameter of the hole to be drilled must be smaller than the actual overall size of the thread to be cut. An explanation of this is shown in the sketch opposite.



Hole drilled to same size as bar.

Threads cut into metal

The drawing above shows that if a hole was drilled which was the same size as the threaded bar, the bar would just fall through. The hole which must be drilled must therefore be smaller in diameter so as to allow the TAP to cut the threads.

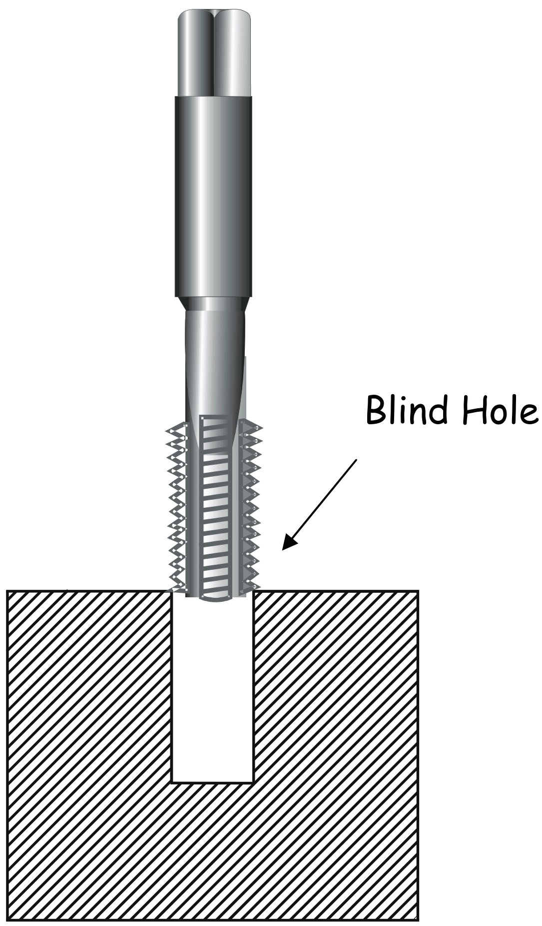
Drilling Data

The table opposite shows the diameter of hole which would be required to be drilled prior to tapping. E.g. if an M5 (Metric 5mm) thread has to be cut, the size of hole to be drilled will be 4.2mm.

ISO Metric Coarse Pitch Threads		
Diameter	**Tapping**	**Clearance**
M2	**1.6mm**	**2.5mm**
M2.5	**2.1mm**	**3.0mm**
M3	**2.5mm**	**3.5mm**
M4	**3.3mm**	**4.5mm**
M5	**4.2mm**	**5.5mm**
M6	**5.0mm**	**6.5mm**
M8	**6.8mm**	**8.5mm**
M10	**8.5mm**	**10.5mm**
M12	**10.2mm**	**13.0mm**

Blind Hole

A blind hole is a hole which has a bottom to it. If a blind hole is to be threaded it is very important to ensure that the depth of the hole is established before commencing to thread the hole. If this is not established it would be very easy to break the taps. A piece of tape attached to the tap indicating the depth is an ideal way of avoiding the tap from being broken by being forced into the bottom of the hole.



External Screw Cutting

In the previous few pages internal screw cutting was explored. External screw cutting will now be investigated. To cut an external thread on a metal rod a tool called a **DIE** will be used.

Circular Split Die

The picture opposite shows a split die, this is the most common type of die used in the school workshop. These are used for cutting external threads. The die is made from high speed steel (HSS). To assist in starting the thread cut, the split die has a split which enables the die to be opened slightly thus cutting a shallower cut.

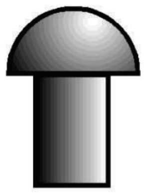
Die Holder or Stock

The circular split die fits into the die stock with the tapered side of the thread (shown by the writing on the die). The split in the die fits opposite the centre screw to allow the opening and closing of the die. The two screws at the side hold the die in the stock To ensure the die can start to create a thread on the rod the rod must firstly be tapered at the end.

Riveting

Riveting is the process of joining two or more pieces of metal together permanently. The process uses metal plugs, more commonly known as rivets. To form the joint, the shank of the rivet is passed through a previously drilled hole in the components to be joined, it is then cut to size and spread or shaped, thus preventing the parts from separating. Sketches of the process are shown overleaf.

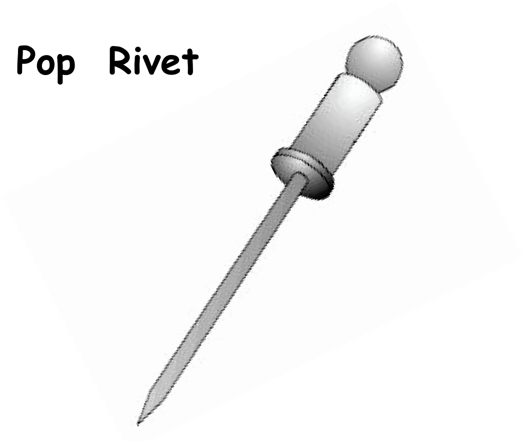
Rivets are classified by the shape of the head, their diameter and length. Common rivet head shapes are round (or snap), countersunk, pan and flat. Other types of rivet found in the workshop are BIFURCATED and POP rivets. In general the type of work at hand will determine the type of rivet to use.



Snap Head

Countersink Rivet

Pop Rivet

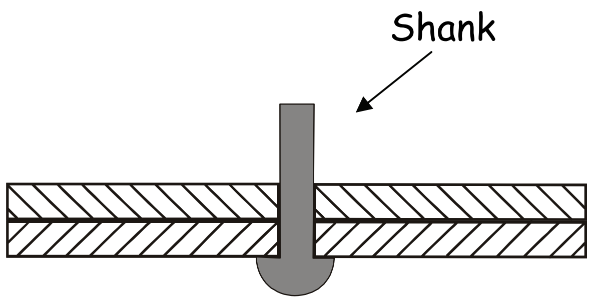


Flat Head

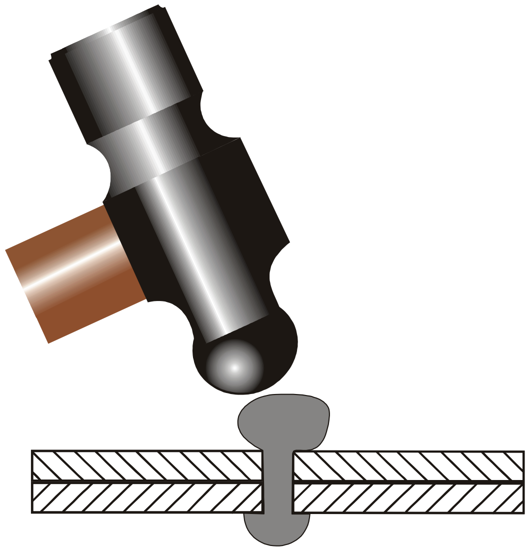
Rivets are made in most types of metal; e.g. mild steel, copper, stainless steel, brass, aluminium. When using a rivet always ensure that the rivet being used is the same material as the metals being joined or it will result in aggravated corrosion at the rivet site.

Snap Head Riviting

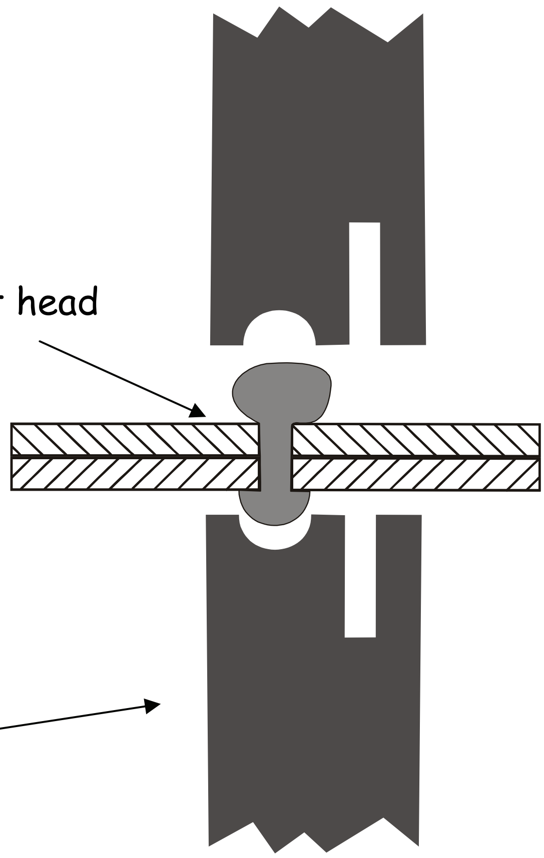
In the sketch shown opposite the rivet is placed through the two sheets of metal. The shank of the rivet is then cut to the desired length. This length is generally 1.5 times the diameter of the rivet. E.g. if the diameter of the rivet is 5mm then the length to be measured above the sheet metal on the shank will be **5mm x 1.5 = 7.5mm.**



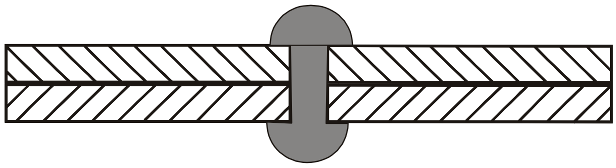
The next stage of the operation is to shape the shank of the rivet to the approximate shape of the final head using the Ball Pien hammer.



The final stage is to place one rivet set into an Engineers vice, place the rounded head of the rivet into the indent in the rivet set as shown. Next place the other half of the rivet set on top of the shaped head and hit it with a hammer until desired shaped has been achieved.



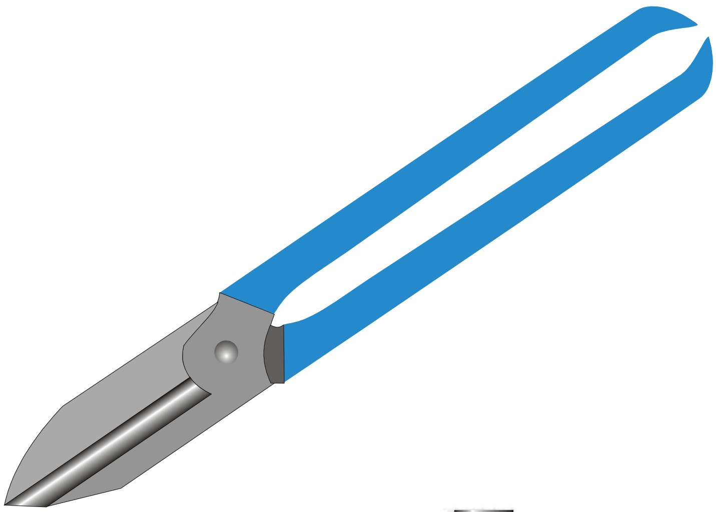
The sketch opposite shows the completed riveting of two sheets of metal using a snap head rivet.



Snap and Rivit Set

Tin Snips

Tin snips, as the name implies, cut sheet tin and most other sheets of metal. The blade of the snips come in either straight or curved form.



"V" Block

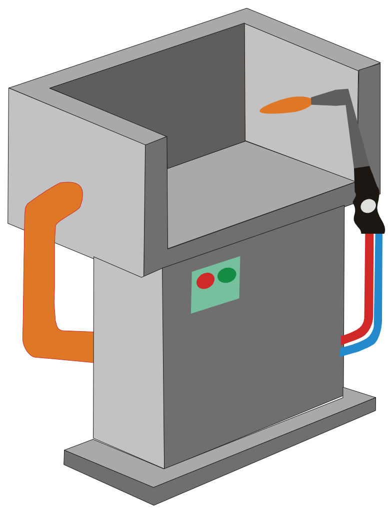
The "v" block is primarily used for securing pipes, rods, etc. to enable work to be carried out on them.

Heat Treatment

When a metal is cold worked, i.e. when it is cut, beaten, hammered, bent, twisted or shaped, etc. at normal room temperature, tremendous internal forces are set up within its grain structure and the metal becomes extremely hard and liable to split. The term 'heat treatment' is applied to metals that undergo some form of heating process in order to change their properties. Generally, any heating process carried out on a solid metal is referred to as heat treatment. Heat treatments involve processes such as annealing, normalising, forging, hardening, tempering, etc.

Anvil

Forge



Work Hardened

If a material has been bent, hammered or twisted consistently over a period of time the metal will be **Work Hardened.** What is meant by this, is, the tiny molecules which make up the metal have been pushed and twisted out of their original positions thus making the metal very liable to breaking. This can be fixed by **Annealing** the metal.

Annealing

This process makes the metal as soft as possible to relieve the internal stresses, and make it easier to shape. The annealing process generally involves heating up to a certain temperature and allowing to cool, either in the air or in water depending on the material being annealed. If soap is applied to Aluminium prior to heating it will turn **Black** when the correct temperature has been reached.

Tempering

This process involves heating the metal to various temperatures and then immediately quenching it in water. As the metal is being heated it changes colour starting with a pale straw to dark straw to reddish brown to purple then dark blue. Dependant on what properties are required of the steel being tempered will determines what heat it will be heated to. E.g. when it reaches a dark blue colour it is at 300° C. These colours are known as TEMPERING COLOURS.

Case Hardening

Mild steel cannot be hardened and tempered as its carbon content is too low. What can be done is to provide it with a hard outer case. In this process the metal is heated to a bright red heat and then rolled in a carbon rich powder. The carbon is absorbed into the skin of the metal thus making it very hard on the outer skin. This type of metal is ideal for components such as gear wheels which require to be hard wearing.

Hardening

To enable carbon steel (i.e. tool steel) to be used for the wide variety of tools and articles that are necessary in the school workshop and in industry it must first be hardened, then tempered.

Taking a high carbon screwdriver blade for example, this is HARDENED by heating it slowly to a dull cherry colour and then quenching it in oil or tepid water. When this part of the process has been carried out, it is unusable. Although it is very hard it is also very brittle (i.e. it can break very easily). To make the hardened steel usable it must now be TEMPERED, i.e. given properties such as toughness, elasticity, strength.

Malleability

This is the ability of a material to withstand being hammered, rolled or bent without the material breaking.

Ductility

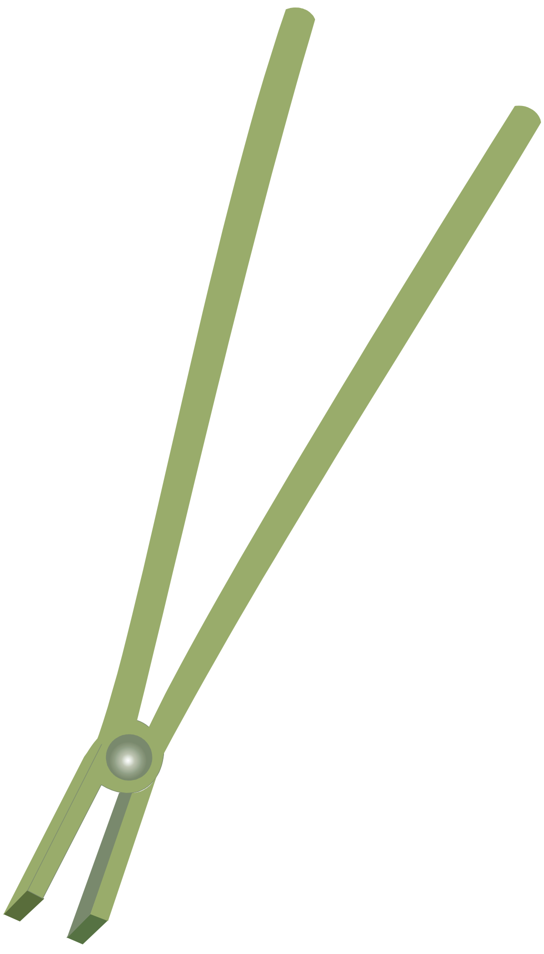
This is the ability of a material to withstand being stretched without the material breaking.

Toughness

This property of the material is the amount of energy it can absorb without breaking and measures its ability to withstand shocks. It is the opposite of brittleness.

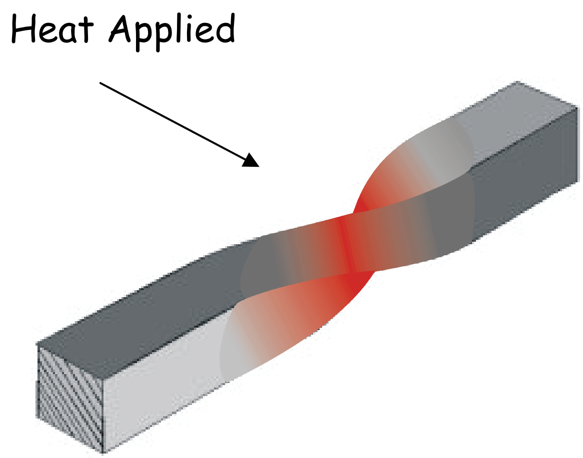
Tongs

When heat treating metals the metal gets extremely hot and therefore great care must be taken when working with it. The tool used to hold the metal being worked is called tongs. These come in a number of different shapes to suit the material being worked.



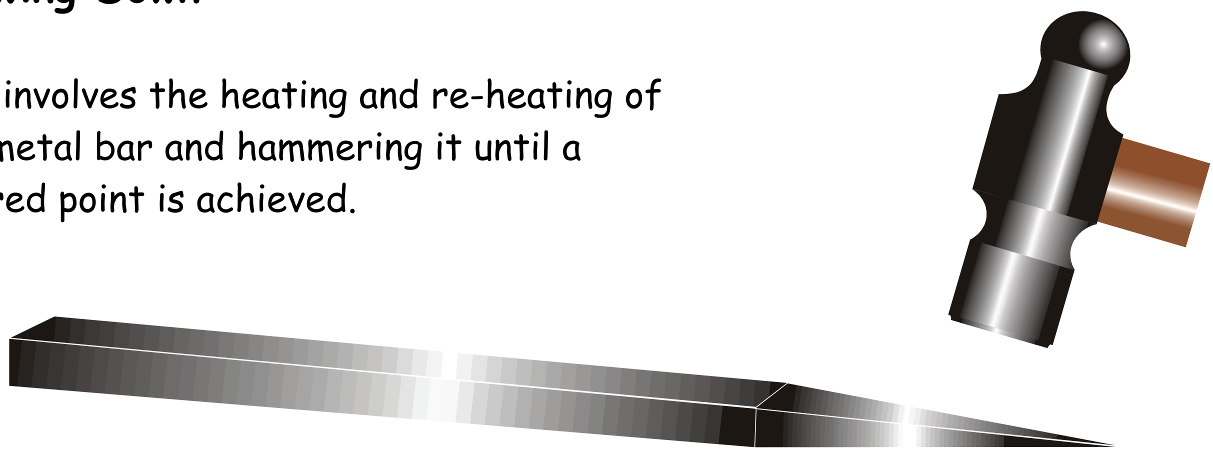
Twisting

As can be seen from the sketch opposite, the metal bar is heated until red hot, it is then twisted to the desired shape.



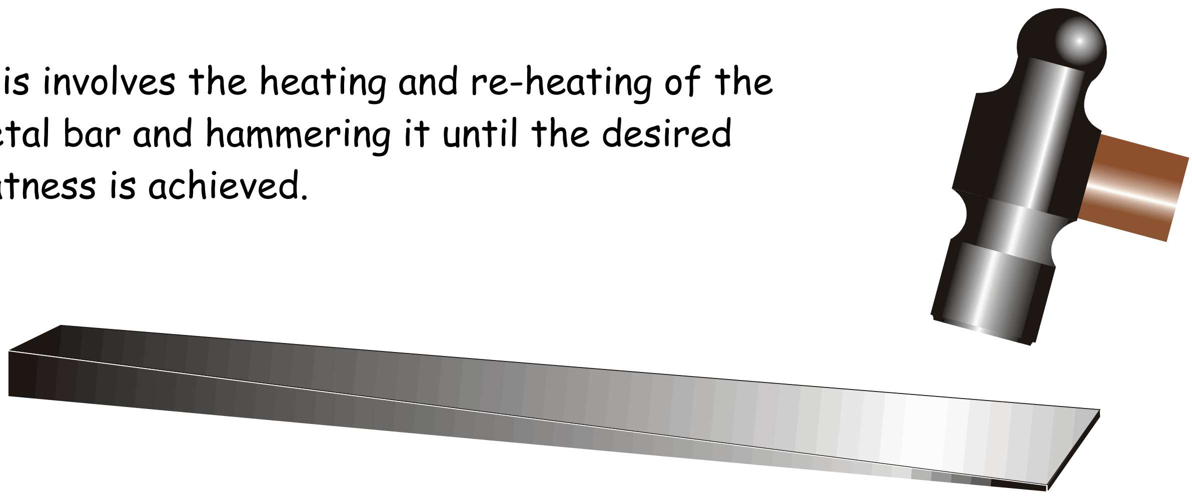
Drawing Down

This involves the heating and re-heating of the metal bar and hammering it until a desired point is achieved.



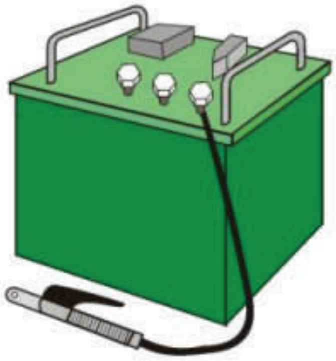
Flattening

This involves the heating and re-heating of the metal bar and hammering it until the desired flatness is achieved.

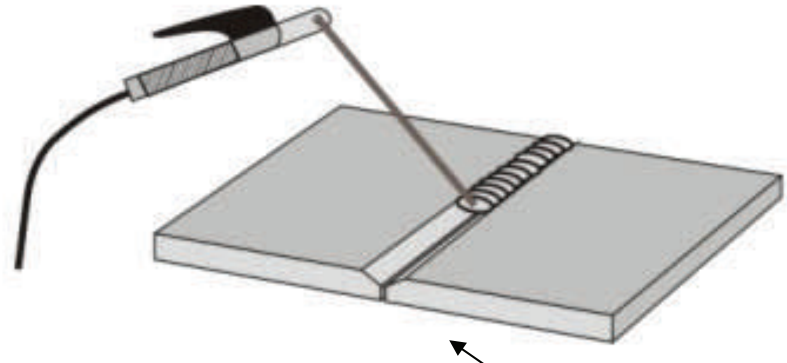


Welding

Welding is the process of joining two pieces of metal together using very high heat and an additional filler metal. The filler metal used must be the same type of metal being permanently joined.



Electric Welding Machine



Two plates being welded together

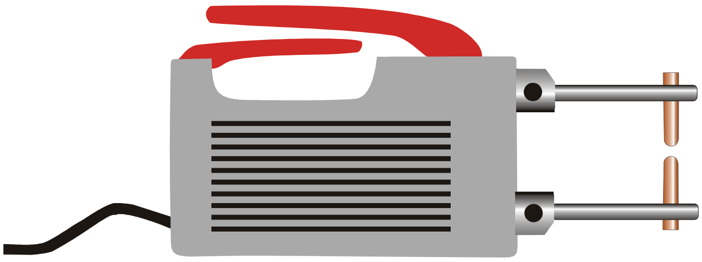
Soldering

Soldering is the process of permanently joining two pieces of metal together using a mixture of tin and lead. Mixing these two metals reduces the overall melting temperature enough to melt the solder using a soldering iron (a heated piece of metal attached to a handle) .

Brazing

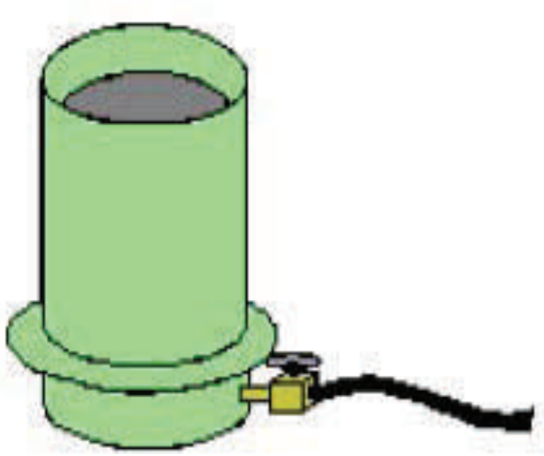
This process is very similar to soldering in that it uses an alloy heated to it's melting temperature to join two pieces of metal together. When Brazing, the filler metal used is called BRAZING SPELTER, which is an alloy of copper and zinc (BRASS). The heat is generated by the use of a blow torch.

Resistance Spot Welding



Resistance spot welding, usually referred to as SPOT WELDING, is the most widely used of this type of welding. As shown in the sketch opposite the overlapping work is positioned between copper electrodes which have reduced area tips to produce welds that are usually from about 1.6mm to 12.5mm in diameter. After the electrodes are closed onto the work piece a high electric current is passed through these points which fuses (melts) the two pieces of metal together.

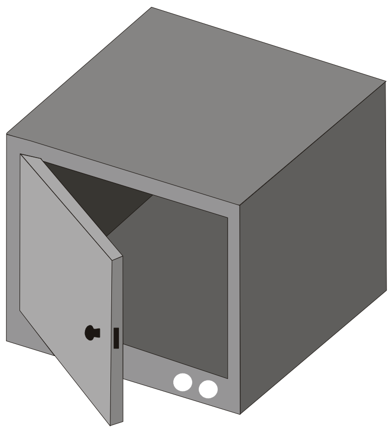
Plastic Dip Coating



Fluidiser

If a ferrous metal is left in the atmosphere for a length of time it will rust. In order to prevent this from occurring a barrier has to be placed between the metal and the atmosphere. One method of doing this is protecting the metal with a plastic coating.

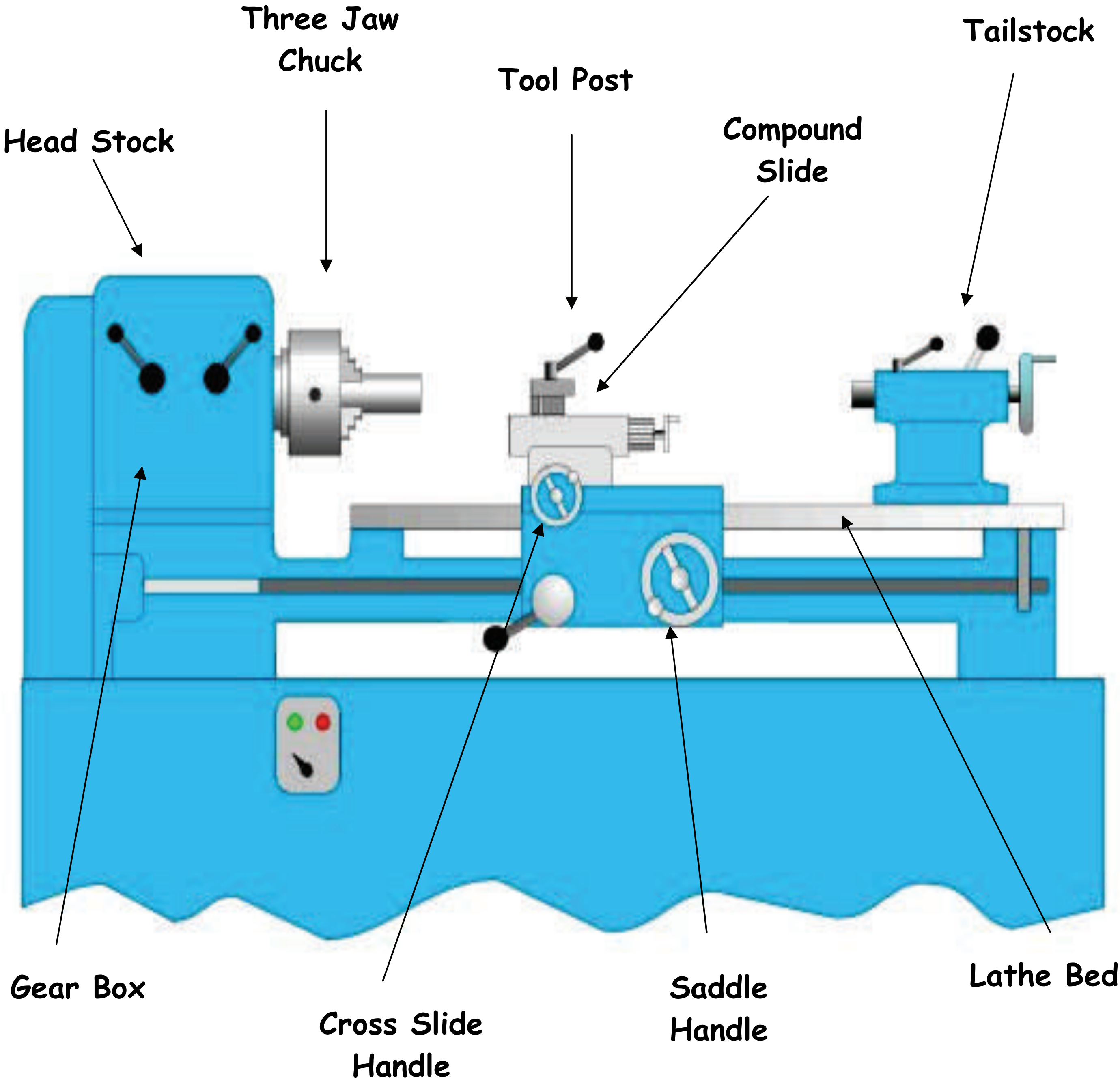
A plastic coating is applied in the following way:-



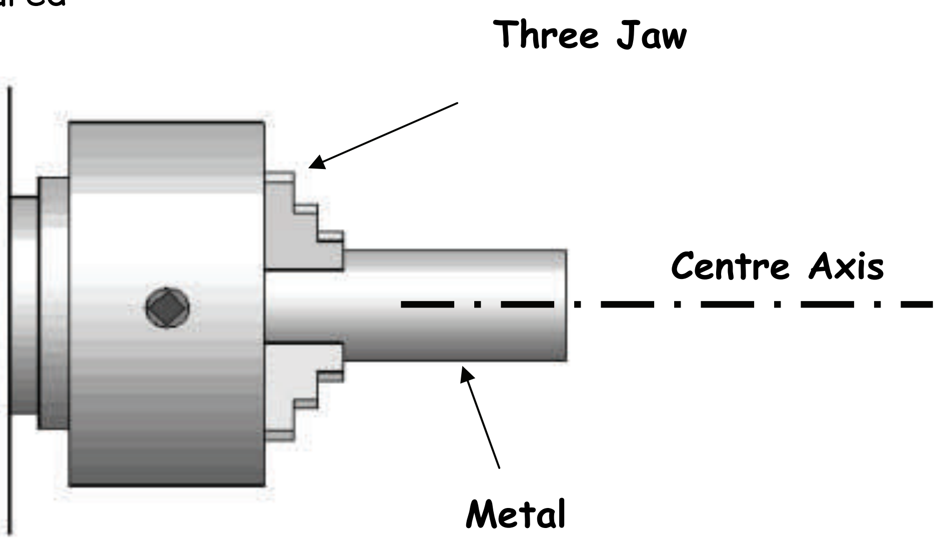
1. Thoroughly clean and degrease the metal.
2. Heat the metal to 180° degree C in an oven.
3. Dip the metal into the fluidised plastics powder for a few seconds.
4. Return it to the oven to fuse the coating to a smooth glass finish. Leave to cool.

Metal Lathe

The purpose of a metal lathe is to shape metal bar into various desired shapes. A typical example is the nut & bolt assembly seen earlier in this booklet. The work piece (metal bar) is secured to a rotating three jaw chuck. The tools which are made from High Speed Steel (HSS) are secured in the tool post. An electric motor spins the work piece to which the cutting tools are then brought into contact with the metal bar.

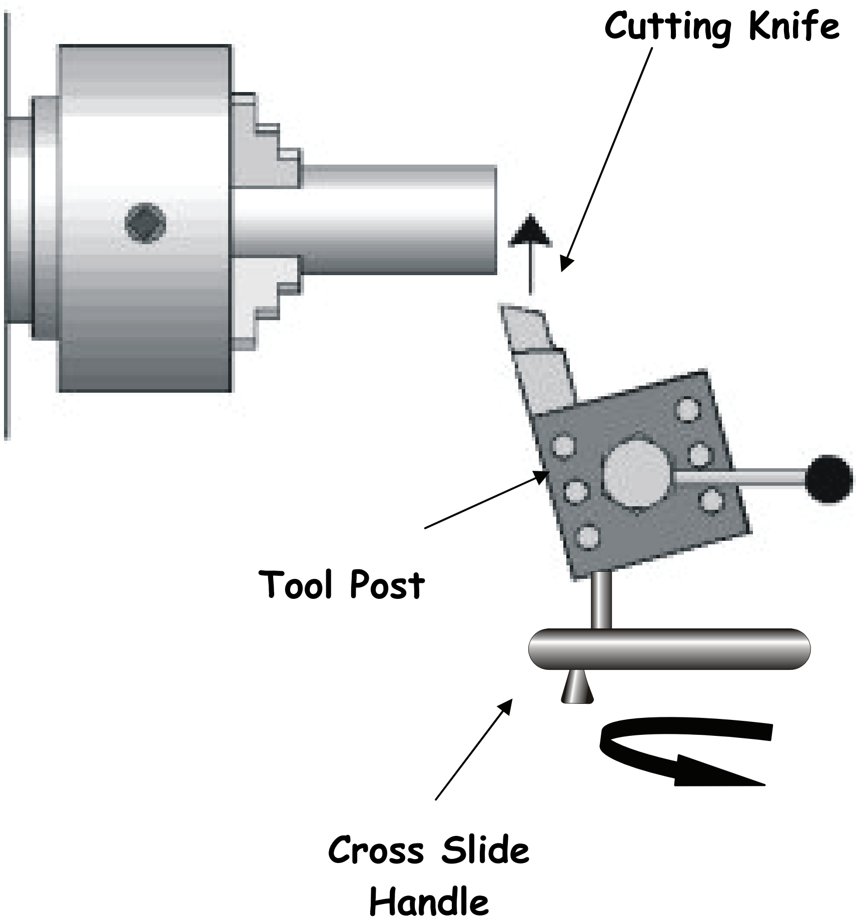


Work piece secured in **THREE JAW CHUCK.**

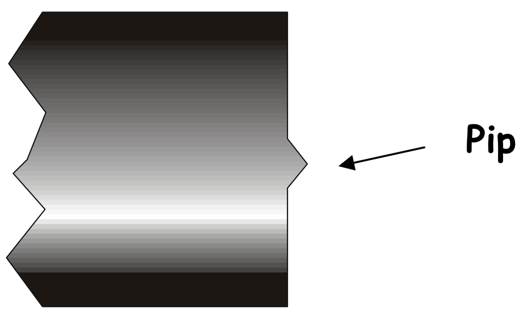


Facing Off

Before starting to shape the metal bar it is essential to face off the end of the bar. This basically means to make the end of the bar perfectly square to the sides of the bar.

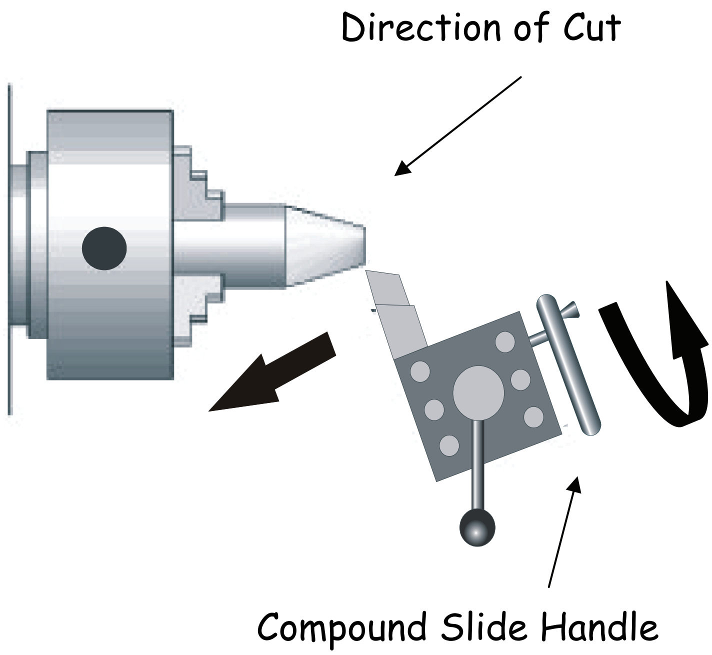


When facing off a piece of round bar it is essential to ensure the cutting knife is lined up centrally to the piece of bar. If it is not a "**pip**" will develop which means the face of the bar will not be truly flat.



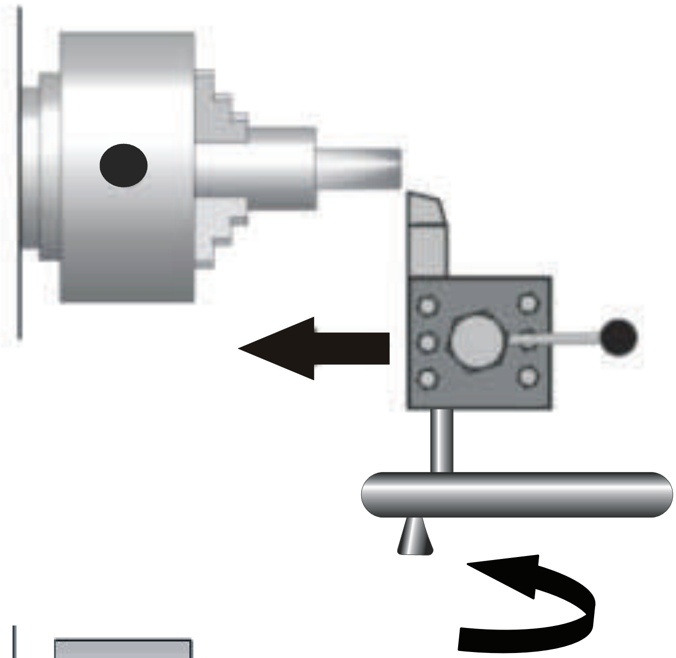
Taper Turning

This is where the tool moves along the bar at an angle moving further away from the centre axis of the bar.



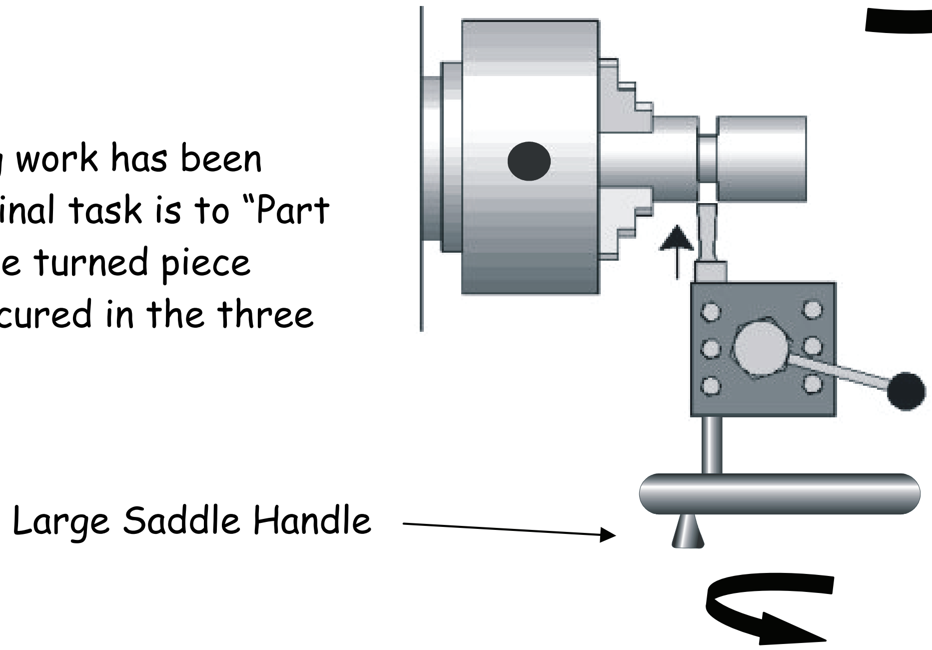
Parallel Turning

This technique moves the tool parallel to the centre axis of the bar as can be seen from the drawing.



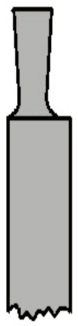
Parting Off

When all turning work has been completed the final task is to "Part Off" (remove the turned piece from the bar secured in the three jaw chuck.



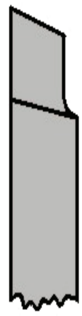
Shown below are commonly used metal lathe cutting tools.

Parting Tool

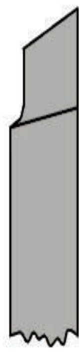


Round Nose

RH Knife

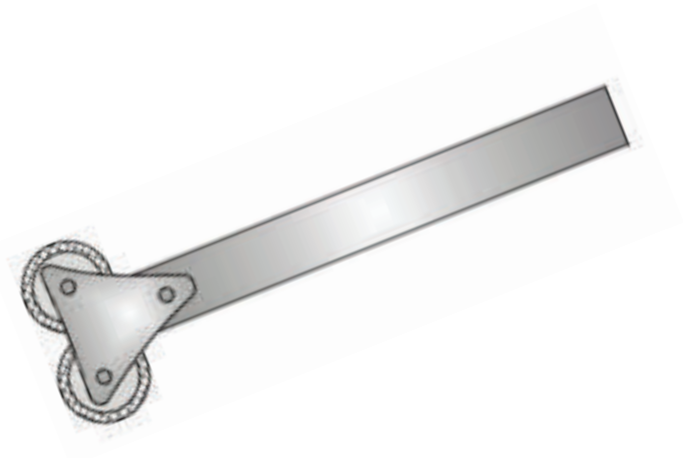


LH Knife



Knurling Tool

This tool is used to **"press"**, NOT cut a straight or diamond pattern into the metal. The process is usually done to provide a hand grip.



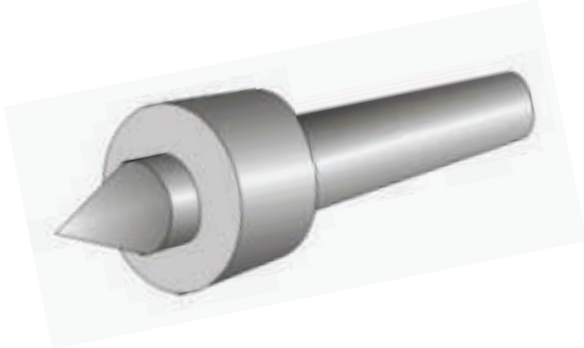
Knurled Bar

Shown opposite is a bar which has been **"knurled"** with a diamond pattern.

Slocombe or Centre Drill

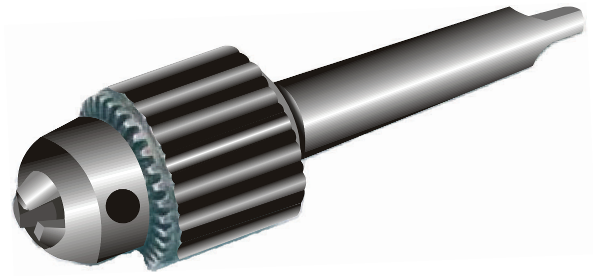
This is a drill and countersink combined. It is used to drill a hole in one end of a piece of bar so as to accommodate the revolving centre as shown below.
As it is not possible to punch holes prior to drilling the centre drill is used first.

Revolving Centre



The revolving centre is secured in the tailstock. The bar to be turned is secured at one end by the chuck and held in place at the other end using the revolving centre. The revolving centre allows the bar to rotate freely allowing turning between centres.

Jacobs Chuck



This tool is placed in the tailstock of the centre lathe and is used to hold twist drills.

Finishing

The purpose of applying a finish to a piece of metal is to protect it from tarnishing or corrosion (rusting). Think of a metal artefact (say a bike) was to be constructed and left outside without any protective coating (paint), how long do you think it would take before it rusted? Not very long! Therefore metals have to be protected from rain, snow, etc. There is a number of ways of doing this depending on the type of metal being protected. The following examples are just some methods of protecting metals.

Painting

Paints are applied to bikes, garden gates, bridges, washing machines, etc because these artefacts are generally made from steel. Paints are usually applied this type of metal because they come in various forms and many colours.

Lacquering

This is very similar to varnishing, it can be applied with a brush or can be sprayed on. The purpose of using this type of finish, is, if the base metal has a nice colour to it e.g. copper or brass, it allows this colour to be seen but at the same time protecting it.

Bluing

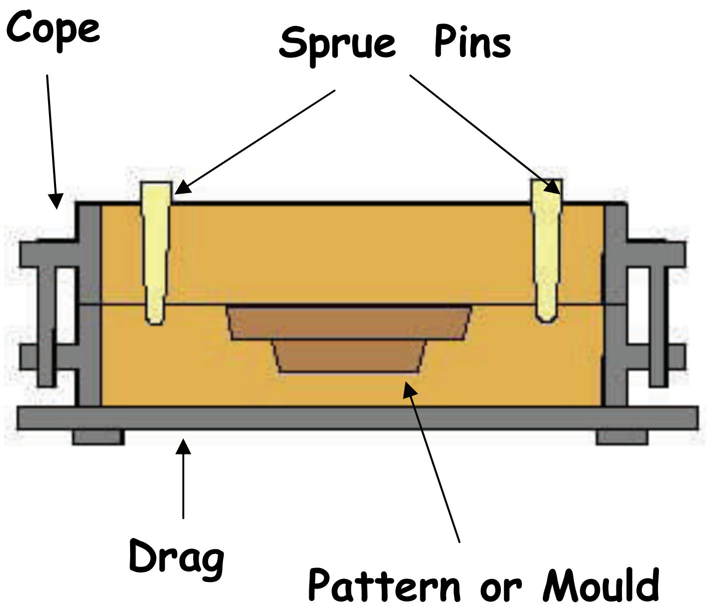
This process involves heating the metal up and dipping it in a bath of oil, leaving it to cool and wiping dry with a cloth.

Sand Casting (Moulding)

Sand casting is the process of making metal shapes (components) using pre-shaped objects and sand. A typical example of an object which has been cast is the Engineers vice which can be found on the workbench. This tool will have been cast in two separate castings. The bottom part of the casting unit which is called a **DRAG** is called so because of the fact that the PATTERN is dragged from the sand. The top half of the casting unit is called the **COPE**.

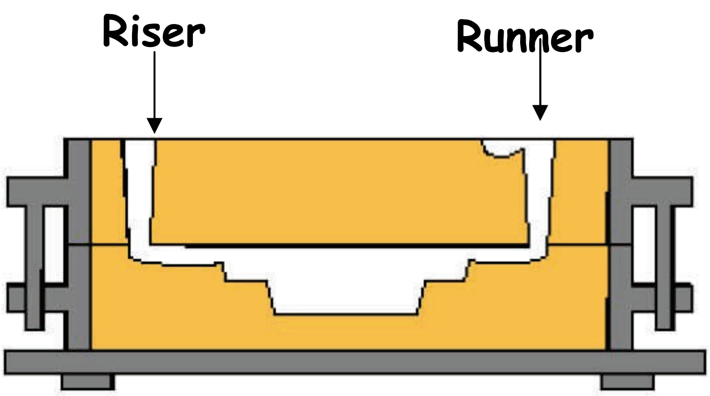
Stage 1

The COPE and DRAG are both filled with wet sand. The pattern (mould) is then pressed into the sand until flush with the surface. As can be seen from the drawing the cope is then placed on top of the drag. Sprue pins are then pushed through the sand to produce a **RUNNER** and a **RISER**. The runner will be the channel in which the molten metal will be poured into the mould.



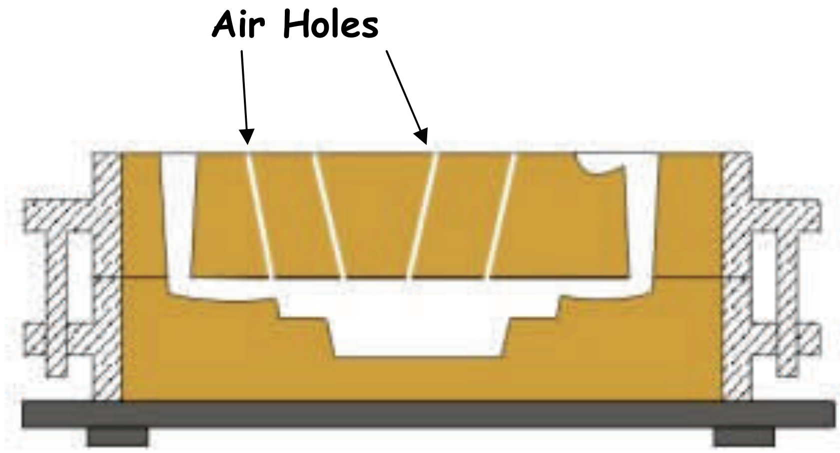
Stage 2

At this stage the wooden pattern has been removed and the riser and runner which were created by the sprue pins have been extended into the space left by the pattern. This will allow molten metal to flow through into the mould.



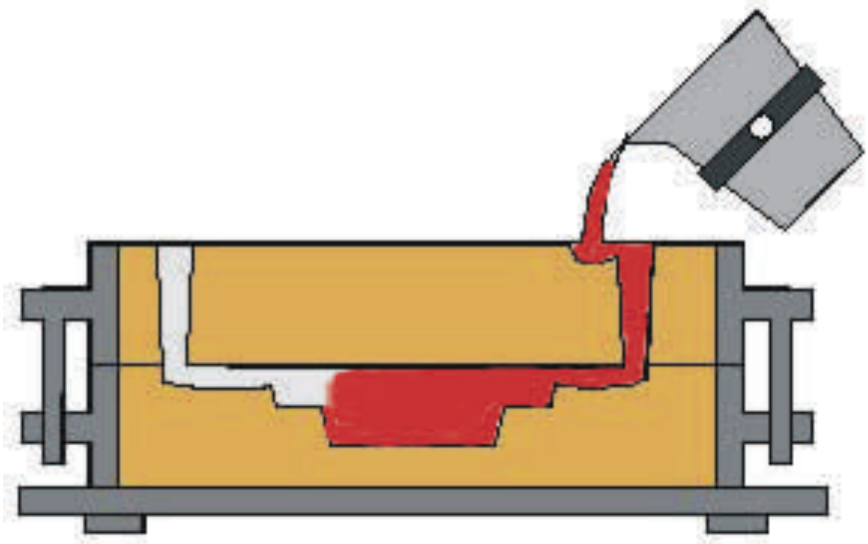
Stage 3

This shows a cross section (cut through the middle) of the pattern and runners. Very narrow holes can be seen, this allows excess air and moisture to escape thus allowing the metal to fill fully all available space in the pattern.

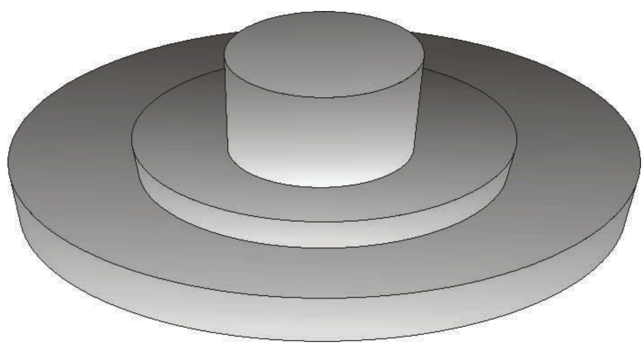


Stage 4

The final stage in the process is to pour the molten metal into the runner. The air which occupies the pattern space is forced out of the riser on the other side. The finished mould is then removed from the sand. The mould will also have extensions attached at this stage in the form of a runner and riser. These will simply be cut off and recycled.



Finished Article



Micrometer

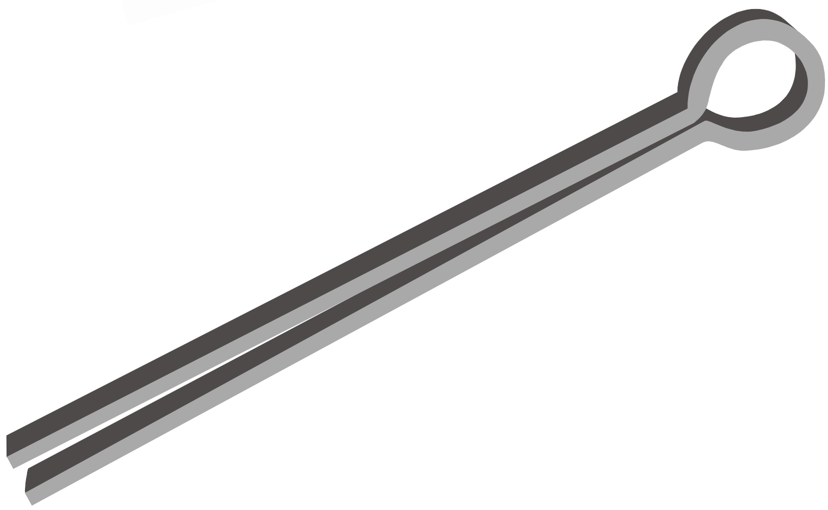
This tool is used to measure sizes with great accuracy. The most commonly used micrometers can measure to one hundredth of a mm. The micrometer is generally used for measuring external sizes.

Vernier Callipers

The vernier callipers are also used for measuring very accurate sizes except the vernier calliper can measure internal sizes, depths and external sizes.

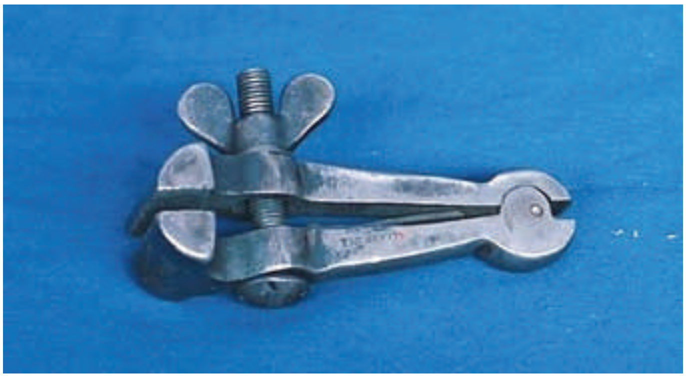
Folding Bars

The folding bar is used when folding sheet metal in order to obtain a straight, neat bend. They are usually held in a vice for small scale work.



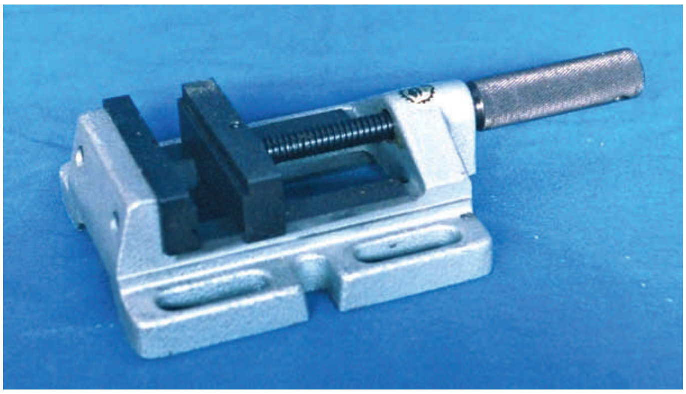
Hand Vice

This is used for holding small and especially irregular shaped parts while drilling, riveting etc.



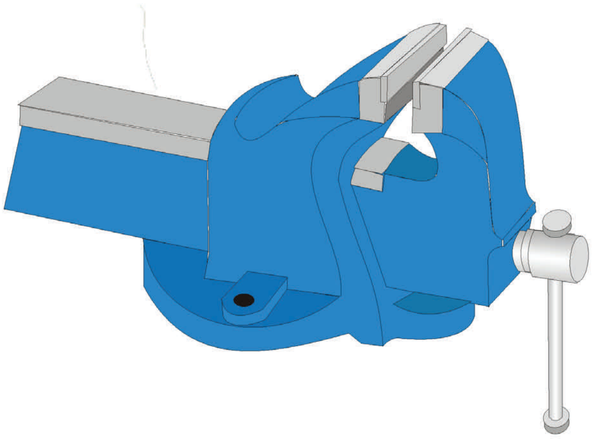
Machine Vice

This type of vice is used to hold heavier pieces of metal while drilling. The main body of the vice has been CAST in a mould. The handle of the vice has been KNURLED.



Engineer's Vice

The vice is bolted to the bench top so as to ensure the vice does not move while working on it. The vice is used primarily to hold metal while cutting, sawing, filing, etc. are carried out. As with the machine vice the body has also been CAST in two separate pieces.



Toolmaker's Clamp

These are used to hold parts together while marking out, shaping and drilling.