Metals & Alloys

Including:

• Ferrous
• Non- Ferrous
• Alloys
• Processes
• Joining
• Finishing
Introduction

Metal Most metals are found in the ground as ore (rocks). All of the rocks in the picture here contain the ore for a different kind of metal.

Mining

Smelting

Pure Metal and Waste (slag)

There are two categories which metals can be placed in:

- Ferrous
- Non-Ferrous

- **Ferrous** metals contain iron and are magnetic. These metals will rust.

- **Non-Ferrous** metals do not contain iron and are non-magnetic. These metals will not rust.
### Metals Properties Terminology

<table>
<thead>
<tr>
<th>Property</th>
<th>Terminology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elasticity</td>
<td>Ability to return to shape after deformation.</td>
</tr>
<tr>
<td>Toughness</td>
<td>Ability to withstand sudden loading (impact resistant).</td>
</tr>
<tr>
<td>Brittleness</td>
<td>Ability to snap easily.</td>
</tr>
<tr>
<td>Malleability</td>
<td>Ability to be hammered into shape without fracturing.</td>
</tr>
<tr>
<td>Hardness</td>
<td>Resistant to wear and indentation.</td>
</tr>
<tr>
<td>Ductile</td>
<td>Ability to be stretched (drawn) to a reduction cross-section.</td>
</tr>
</tbody>
</table>
## Ferrous Metals

<table>
<thead>
<tr>
<th>Name</th>
<th>Colour</th>
<th>Properties and working characteristics</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild Steel</td>
<td>Black/Grey</td>
<td>Malleable/ductile, uniform texture.</td>
<td>Nuts, bolts, screws, tubes, girders, car bodies.</td>
</tr>
<tr>
<td>High carbon Steel</td>
<td>Black/Grey</td>
<td>Malleable/ductile, can be hardened and tempered.</td>
<td>Cutting tools, files, drills, saws, knives, hammers, taps and dies.</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>Silver/Grey</td>
<td>Not readily corrode, rust or stain with water making it hygienic. It is a versatile and durable metal.</td>
<td>Cookware, cutlery, household hardware, surgical instruments, major appliances</td>
</tr>
<tr>
<td>High Speed Steel</td>
<td>Black/Grey</td>
<td>It can withstand higher temperatures without losing its temper (hardness). This allows it to cut faster than high carbon steel.</td>
<td>Drills, taps, milling cutters, tool bits, gear cutters, saw blades, files, chisels, hand plane blades. Usage for punches and dies is increasing</td>
</tr>
</tbody>
</table>
## Non Ferrous Metals

The following metals below are ‘Pure Metals’ and have not been mixed with any other material.

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<tr>
<td>Aluminium</td>
<td>Silver</td>
<td>Good strength to weight ratio, casts easily.</td>
<td>Window frames, cans, pots and pans.</td>
</tr>
<tr>
<td>Copper</td>
<td>Orange/Gold</td>
<td>Ductile/malleable, low melting point, expensive.</td>
<td>Central heating pipes, electric wiring/cable, jewellery.</td>
</tr>
<tr>
<td>Tin</td>
<td>Silver/White</td>
<td>Heavy/soft, low melting point.</td>
<td>Bearings, solder, coating sheet steel.</td>
</tr>
<tr>
<td>Lead</td>
<td>Dull/Greyish</td>
<td>Heavy/weak/soft, ductile/malleable, low melting point, can be cast.</td>
<td>Roof flashing, soldering. Was previously used for piping in houses.</td>
</tr>
<tr>
<td>Zinc</td>
<td>Silver/Grey</td>
<td>Weak, difficult to work.</td>
<td>Galvanising</td>
</tr>
</tbody>
</table>
Alloys are a mixture of metals and/or other elements combined together resulting in superior properties such as; strength, hardness, durability, ductility, tensile strength and toughness. Ferrous alloys range from plain carbon steels, with 98% iron, to high alloy steels, with up to 50% of other elements.

Alloys are sometimes described as a mixture of two or more metals. However, this is misleading, as often alloys are composed of just one metal, as well as other non-metal elements. Mild Steel is an example, as it is a combination of iron (metal) and carbon (non-metal).

For example, mild steel is 0.1 - 0.3% Carbon and 99.9 - 99.7% Iron.
## Metal Alloys

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Brass</td>
<td>Gold-like appearance</td>
<td>Copper and Zinc</td>
<td>Relatively low melting point and easy to cast. By varying the amounts of copper and zinc, brass can be harder or softer. Today almost 90% of all brass alloys are recycled. It has good acoustic properties.</td>
<td>Musical instruments: trombone, tuba, trumpet, etc.</td>
</tr>
<tr>
<td>Bronze</td>
<td>Metallic brown colour</td>
<td>Copper and Tin</td>
<td>Bronzes are softer and weaker than steel. They resists corrosion (especially seawater corrosion) and metal fatigue more than steel. It’s also a better conductor of heat and electricity than most steels.</td>
<td>Boat/ship fittings prior to stainless steel. Sculpture/statues. Bearings, clips, electrical connectors and springs. Musical instruments: cymbals and bells.</td>
</tr>
</tbody>
</table>
### Non Ferrous Alloys

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<tr>
<td>Duralumin</td>
<td>Black/Grey/Silver</td>
<td>Aluminium, Copper, manganese and magnesium</td>
<td>It is hard and tough lightweight alloy of aluminium. Relatively soft, ductile, and workable.</td>
<td>Widely used in aircraft construction. It may be rolled, forged, extruded, or drawn into a variety of shapes and products.</td>
</tr>
<tr>
<td>Soft Solders</td>
<td>Silver/Grey</td>
<td>Tin/Lead</td>
<td>Joins together metal and has a melting point below that of the work piece. Alloys that melt between 180 and 190 °C (360 and 370 °F) are the most commonly used.</td>
<td>It is commonly used in electronics and plumbing, and when manually applied is often done so using a soldering iron or soldering gun</td>
</tr>
</tbody>
</table>
Shown below is a diagram of a simple metal lathe with each part labelled. The lathe creates cylindrical shapes with a variety of different profiles.

https://www.youtube.com/watch?v=9dk0qZFLKvo
Die casting is used to produce engineered metal parts by forcing molten metal under high pressure into steel moulds. These moulds, called dies, can be designed to produce complex shapes which are very accurate and can be used over again. The parts can be made with a variety of smooth or textured surfaces.

http://www.youtube.com/watch?v=1AgDGLNE6Es

Advantages of Die Casting
- Very accurate to low tolerances.
- The mould can be used over and over again.
- The process can be fully automated.

Disadvantages of Die Casting
- The initial cost is usually very high.
- This process is limited to high fluidity metals.
- The parts that can be made must be quite small compared to other processes that can manufacture much larger items.
- The moulds are expensive to make and can only be used to make one part.

Suitable Materials
- Low melting temperature alloys:
  - Zinc
  - Lead
  - Aluminum
  - Brass alloys

Identifying Features
- Section hair lines
- Ejector pin marks
- Flashes caused by leakages on internal surfaces (these do not interfere with performance or appearance)
- Sprue and runner marks (where it has been injected)

Example Products
- Sharpener
- Toy Car
- Car Engine
- Nut Cracker.

Die cast items are one of the most commonly mass produced items. This is a good choice for large scale mass production.
Sand Casting

Sand casting is another process that is used to form molten metal into a shape as a product or a component. Sand casting uses dense sand called *casting sand* to shape out moulds with.

http://www.youtube.com/watch?v=rgL2Jn5mk1A

### Advantages of Sand Casting
- The initial cost is quite cheap.
- It is a fairly easy process – no skilled operators needed.
- Can produce much larger components and items than other casting methods.
- Limited waste of materials – casting sand can be used repeatedly to make different moulds.

### Disadvantages of Sand Casting
- Almost always requires human involvement.
- Not really suitable for large mass production numbers, as the moulds do not last as well as others.
- Produces a poor surface finish compared to other methods.
- A more dangerous process, as human involvement is needed.

Due to the rough, poorer finish and slower production time, sand casting is normally used for prototypes and small number productions. Other processes are usually better options for large scale, top quality mass production lines.

### Suitable Materials
- Iron
- Aluminum
- Non ferrous alloys

### Identifying Features
- Solid 3D shapes.
- Poor furnace finish.
- Fillets and rounded corners.
- Strengthening webs.
- Fettle marks due to removal of runners and risers.

### Example Products
- Jewellery
- Engine
- Tools
A **milling machine** is a machine tool used to machine solid materials. Milling machines are often classed in two basic forms, horizontal and vertical, which refers to the orientation of the main spindle. Both types range in size from small, bench-mounted devices to room-sized machines.

http://www.youtube.com/watch?v=U99asuDT97I

**Suitable Materials**
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**Identifying Features**
- 

**Example Products**
- Keys.
- Machined Parts
Piercing and Blanking are shearing processes in which a punch and die are used to cut of metal. The tooling and processes are the same between the two, only the terminology is different:
- **Piercing** the punched out piece is scrap.
- **Blanking** the punched out piece is used and called a *blank*.

**Progressive piercing and blanking**
This is when the sheet metal is feed along the machine and they are cut simultaneously. The waste material ‘the piercing’ is down first. Then the material is moved along and is blanked.

The outside circular shape of the washer would then be blanked.

The inside hole would be pierced first.

**Suitable Materials**
- Sheet metals: they are normal annealed (heat treatment) to minimize fracture risks.

**Identifying Features**
- Sheared Surface.

**Example Products**
- Door Hinge
- Key Ring
- Jewellery
- Washers

[Image of products: Door Hinge, Key Ring, Jewellery, Washers]

[Video Link] http://www.youtube.com/watch?v=XgimpyHOWN0
Punching

Punching is a metal fabricating process that removes a scrap slug from the metal workpiece, using a punch, via shearing. The scrap drops through the die and is normally collected for recycling. It can be done manually or automated.

Example Products

- Panels
- Lanterns
- Furniture

Suitable Materials

- Sheet Metal:
  - Mild Steel
  - Stainless Steel
  - Aluminum
  - Galvanized Steel
  - Various Plated Metals

Identifying Features

- Sheared Surface.

https://www.youtube.com/watch?v=R_BH1IR2_jA
Press Forming

This process is completed using a large pressing machine. Press forming is usually used to form sheet metal into a required shape.

Stage 1.
The sheet metal is cut to size and entered into the machine.

Stage 2.
The machine presses down on the sheet metal with a huge amount of force, bending the metal into the pattern as shown above.

Stage 3.
The metal is released and is now formed into the required shape.

Example Products
- Stainless Steel Sink
- Pans
- Kettle
- Aircraft Panels
- Car Bodies

Suitable Materials
- Sheet metals: various steels, aluminum alloys, brass, copper.

Identifying Features
- Sudden directional change.
- Ribs and piercings.
Drop Forging

Drop forging is used to produce high quality, strong metal components and products. The main advantages are that components can be accurately repeated using specially shaped dies (moulds). Drop forging process is where a hammer is raised and then "dropped" onto the work piece to deform it according to the shape of the die.

Suitable Materials
• Most metal alloys are suitable with Alloy steels and copper being most common.

Identifying Features
• Flashing or flash removal around the shape.

Example Products
• Hammer Heads
• Spanners
• Corkscrew
• Metal Fences

http://www.youtube.com/watch?v=leXpTLV3HMQ
Stamping

Metal stamping is done manually, onto sheet metal, using stamps and a hammer and come in a wide variety of designs from: letters, numbers or graphics.

Suitable Materials
• Sheet Metal.

Identifying Features
• Indentations in metal.

Example Products
• Key rings
• Jewellery
Sheet metal such as aluminium is usually quite easy to bend and fold to a certain angle or size. The most common way of doing this is by using a folding machine such as the one shown below.

**Example Products**
- Chairs
- Brackets
- Panels

**Identifying Features**
- Folds and bends in metal

**Suitable Materials**
- Sheet Metal.
- Metal Bar.
# Lost Cast Waxing

Lost wax casting is the process by which a duplicate metal sculpture (often silver, gold, brass or bronze) is cast from an original sculpture.

1. Carve required shape from wax.
2. Attach to base and Place on flask.
3. Make a plaster mixture know as the ‘investment’.
4. Pour investment mixture into flask to cover the wax mould.
5. Vacuum investment mixture to remove air bubbles.
6. Allow investment mixture to set.
7. Place flask in kiln to melt and remove wax.
8. Heat metal to required temperature until molten.
9. Pour molten metal into mould and allow to set. You can also quench it in water.
10. Remove from flask and clean.

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### Suitable Materials
- Silver
- Bronze
- Brass
- Aluminum
- Gold

### Identifying Features
- One piece construction.
- Intricate detail.
- Smooth or textured finish.

### Example Products
- Jewellery
- Bespoke sculptures

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https://www.youtube.com/watch?v=tnSDQpTfKeo
Hardening and Tempering

Hardening and tempering is a process which is done to metal in order to make it a lot more durable and less brittle. Most commonly to steel to strengthen tools or products which must be able to withstand cracking and/or snapping.

Stage 1.
Slowly heat the entire length of metal until it becomes red hot.

Stage 2.
The metal is cooled rapidly in water, at this stage, the metal is very brittle and would snap quite easily.

Stage 3.
Another even spread of heat is applied to the metal until the metal goes blue in colour.

Stage 4.
The metal is removed and placed on a cool steel surface. This allows the metal to completely cool. The material will now be much more hard wearing and durable than it was before.
Cutting

There are a wide variety of ways to cut metal and some manual processes are shown below.

**Hack Saw**
The hacksaw is used to cut steel and other metals.

**Junior Hack Saw**
Junior hacksaws have the same function but are used on small pieces of material.

**Guillotine**
The guillotine shears metal cutting it at the line required.

**Tin Snips**
Tin snips are used to cut sheet metal and come in a variety of different shapes.

**Notcher**
Notching is a metal-cutting process used on sheetmetal or thin barstock, shearing or punching the metal to remove waste metal.
Here are some automated processes used in industry to cut metal.

**Rotary Shearing Machine**
A rotary shearing machine is automated to shear sheet metal at a requested distance.

https://www.youtube.com/watch?v=pKHyQPFA-jI

**Plasma Cutter**
Plasma cutting is a process that is used to cut steel and other metals of different thicknesses (or sometimes other materials) using a plasma torch. It can be used to cut the full way through or engrave on to a surface.

https://www.youtube.com/watch?v=9tNWQwM96qY
https://www.youtube.com/watch?v=pKHyQPFA-jI
https://www.youtube.com/watch?v=f5TwzRW_DtY
Permanent Joining

Spot Welding

Metal sheets are joined by the heat obtained from resistance to electric current flow.

Work-pieces are held together under pressure exerted by electrodes. Typically the sheets are in the 0.5 to 3 mm thick. The process uses two shaped copper alloy electrodes to concentrate welding current into a small "spot".

Arc Welding

Heat is obtained by an electric arc via a power supply. One lead is attached to the work and the other to a grip holding a welding rod. An arc is formed when the end of the rob is brought near the work. The heat melts the parent metal and the filler rod together.

http://www.youtube.com/watch?v=z44AlvQimm0
http://www.youtube.com/watch?v=g6AEJWzAsu0
Permanent Joining

Riveting

There are two methods of riveting: Traditional Riveting and Pop Riveting.

**Traditional Riveting** with soft iron, aluminium or copper for snap, countersunk and flat head rivets. These are formed using a hammer and rivet set.

**Pop Riveting** with rivet guns are used when avoiding the use of a hammer.

Drill hole for pop rivet.

http://www.youtube.com/watch?v=9aoXmzdSf_I
Fitted Joints

Metal can be fitted together to join it e.g. copper piping. These fitted joints can be reinforced with solder, welding or adhesives.
Non Permanent Joining

Bolts

The screw thread has the advantage of enabling items to be taken apart for inspection or maintenance purposes. Nuts and Bolts can be obtained in various forms. There are numerous designs of spanners for use with square and hexagonal headed nuts and bolts.
Screws

Screws are used to fit materials such as chipboard, MDF and natural woods together. They are a good way of fixing materials temporarily.

**Countersunk/slot-head:** This can be used for general woodworking for example fitting hinges to doors. Because the screw is countersunk it can be tightened 'flush' to the surface of the material.

**Pozidrive head:** Used with special screw drivers which will not slip when pressure is applied. This is ideal when using screws in corners or confined spaces.

**Round head:** These are used for fixing pieces of material together where countersunk holes are not being used. Round head screws can look quite decorative especially if they are made of brass.
Ferrous

Metals require finishes for protective or aesthetic purposes.
• Ferrous metals contain iron and therefore require a finish to ensure it doesn’t rust.
• Non-ferrous metals and alloys don’t require a finish as they are designed not to rust.

Plastic
Dip Coating
• The metal is heated and dipped into plastic powder which then metals to create a coating.

Metal Paint
• This can be used in conjunction with a metal primer to help stop rust.

Varnishes and Lacquers
• used for a clear seal on the metal.

http://www.bing.com/videos/search?q=How+to+Powder+Coat&Form=VQFRVP#view=detail&mid=40439DE328D6643CB1D440439DE328D6643CB1D4
Revision Task

Below are a number of products, based on the colours, properties and working characteristics identify what materials they have been made from.

Joining copper pipes?  
Juice Can?  
Trumpet?  
Twist Drill Dit?

Roof flashing?  
Kitchen Sink?  
Ring?
Revision Task

The car wheel shown below is a one-piece aluminium alloy sand casting. It has been chrome plated.

a) Justify the choice of sand casting for the manufacture of this wheel.

b) Explain why additional machining was necessary after sand casting the wheel. A product such as the alloy wheel shown above can also be manufactured by Pressure Die Casting.

c) Explain the benefits gained by manufacturing the wheel using this process.

d) Explain the benefits of using alloys rather than pure metals.
The body of the adjustable spanner shown below is made by the process of drop forging.

a) Explain why drop forging is a suitable process for producing the body of this adjustable spanner.

b) State two features that would indicate that this product was made by drop forging.

c) State a suitable material that could be used for the body of the spanner and give a reason for your choice.