EDEXCEL NATIONAL CERTIFICATE

UNIT 10: PROPERTIES AND APPLICATIONS OF ENGINEERING MATERIALS

NQF LEVEL 3

OUTCOME 2 - TUTORIAL 1
PROPERTIES and PROCESSING OF MATERIALS

2 Understand material properties and the effects of processing on the structure and behaviour of engineering materials

Mechanical properties: strength (tensile, shear, compressive); hardness; toughness; ductility; malleability; elasticity; brittleness
Physical properties: density; melting temperature
Thermal properties: expansivity; conductivity
Electrical and magnetic properties: conductivity; resistivity; permeability; permittivity
Effects of processing metals: recrystallisation temperature; grain structure e.g. hot working, cold working, grain growth; alloying elements in steel e.g. manganese, phosphorous, silicon, sulphur, chromium, nickel
Effects of processing thermoplastic polymers: polymer processing temperature; process parameters e.g. mould temperature, injection pressure, injection speed, mould clamping force, mould open and closed time
Effects of processing thermosetting polymers: process parameters e.g. moulding pressure and time, mould temperature, curing
Effects of processing ceramics: e.g. water content of clay, sintering pressing force, firing temperature
Effects of processing composites: fibres e.g. alignment to the direction of stress, ply direction; de-lamination; matrix/reinforcement ratio on tensile strength; particle reinforcement on cermets
Effects of post-production use: smart materials e.g. impact (piezoelectric), electric field (electro-rheostatic), magnetic field (magneto-rheostatic), temperature (shape memory alloys), colour change (temperature or viscosity)

CONTENTS

1. INTRODUCTION

Engineering components and structures are made from materials carefully selected for their properties and cost. The properties we look for in materials are many. The following explains the important properties. You will find a list of material properties on the web site www.freestudy.co.uk and you should use it to answer the questions.

2. MECHANICAL PROPERTIES

DENSITY

Density is a very important concept. It is a figure that tells us how many kg of a uniform substance is contained in a volume of 1 m^3. The value for pure water is one of the best-known figures since from the old definition that 1 kg was the mass of 1 dm^3 of water then since there are 1000 dm^3 in a the density must be 1000 kg per m^3. This is written in engineering as 1000 kg/m^3. In general density is defined as the ratio of mass to volume and is given the symbol ρ (Greek letter rho). **$\rho = M/V$**

RELATIVE DENSITY

Often the density of substances is compared to that of water and this is the relative density. For example Lead has a mass 11.34 larger than the mass of the same volume of water so the relative density is 11.34. The symbol used is d.

Relative density = d = Mass of a substance ÷ Mass of the same volume of water
If we take 1 m^3 as our volume then d = Mass of 1 m^3 of the substance ÷ 1000
d = Density of the substance ÷1000

MELTING POINT

Pure elements usually have a clear temperature at which they melt or freeze although it depends on the pressure. Many materials (e.g. wood) do not melt.

SELF ASSESSMENT EXERCISE No.1

1. Lead has a density of 11340 kg/m^3. Calculate the volume of 12 kg. What is the melting point?

2. Aluminium has a density of 2710 kg/ m^3. Calculate the relative density. What is the melting point?

3. Seawater has a relative density of 1.036. Calculate the density of sea water.

DUCTILITY

This is a tensile property that allows a material to be drawn (stretched) out into wire. Copper can be pulled out into a long thin wire because it has a large degree of ductility. Cast iron cannot be pulled out in this way and has virtually no ductility. This property is largely defined by the % elongation and % area reduction found in the tensile test.


The picture on the left shows a fracture of a non-ductile metal (probably cast iron) when stretched in a tensile test. The picture on the right shows the fracture of a ductile metal (probably aluminium).

MALLEABILITY

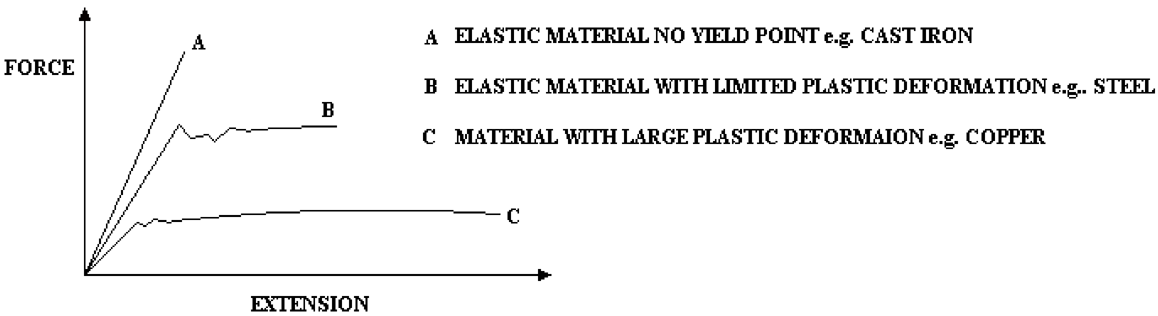
This is a compressive property that allows a material to be beaten (squashed) or rolled into thin sheet. Lead is especially malleable and opposite to glass that has no malleability at all. Other examples of malleable metals are gold, iron and to copper. Gold can be formed into very thin leaf and used to gild other materials like wood and plaster.

STRENGTH

This is the force at which the material will fail. Strength is normally given as the force per unit area or STRESS. There are various ways that a material may fail.

TENSILE STRENGTH

A material may fail when it is stretched in which case it is a tensile failure. The stress at which a material fails is found in a ***TENSILE TEST*** covered in detail OUTCOME 4. The tensile test is carried out with a standard sized specimen and the force required to stretch it, is plotted against the extension. Typical graphs are shown below.



If the material is ductile, we look for the point at which it starts to stretch like a piece of plasticine. This point is called the yield point and when it stretches in this manner, we call it ***PLASTIC DEFORMATION.***

If the material is not ductile, it will snap without becoming plastic. In this case, we look for the stress at which it snaps and this is called the ***ULTIMATE TENSILE STRENGTH***.

Most materials behave like a spring up to the yield point and this is called ***ELASTIC DEFORMATION*** and it will spring back to the same length when the load is removed.

COMPRESSIVE STRENGTH

This is the strength of a material when it is squashed or compressed. Materials are normally very strong in compression because any cracks or faults in the structure will be closed and not pulled apart. Only soft materials like lead will fail easily because they are malleable and will spread out. Materials that are very weak in tension like cast iron and concrete are very strong in compression.

SHEAR STRENGTH
This governs how the material resists being cut in a guillotine or scissors and the ultimate shear stress is the stress at which the material is parted.

TORSIONAL STRENGTH
This governs the stress at which a material fails when it is twisted and a test similar to the tensile test is carried out, only twisting the specimen instead of stretching it. This is a form of shearing.

ELASTICITY
The elasticity of a material governs its ability to spring back to its original shape and size after it has been stretched, compressed, bent or twisted. If too much deformation occurs the material exceeds its ***elastic limit*** and stays deformed. Some materials need more force than others to produce the same deformation and this is governed by its ***modulus***. There are three main moduli.

Modulus of Elasticity E defined as the ratio of tensile stress to strain and determined in a tensile test.
Modulus of Rigidity G defined as the ratio of shear stress and strain and determined in a torsion test.
Bulk Modulus K defined as the ration of pressure and volumetric strain and found with specialised equipment for liquids.
Poisson's ratio ν defined as the ratio of two mutually perpendicular strains and governs how the dimensions of a material change such as reduction in diameter when a bar is stretched.

You should have studies these topics in other modules.

HARDNESS
This governs how a material resists being scratched and resists being worn away by rubbing. The hardness is found with a hardness tester and there are many of these. The main ones are the Brinell, the Vickers and the Rockwell test that basically consists of measuring how far a ball, cone or pyramid can be pressed into the surface. Hard materials are diamonds and glass. Soft materials are copper and lead. Hardness is measured by comparing it to the hardness of natural minerals and the list is called the Moh scale. The list runs from 1 to 10 with 1 being the softest ands 10 the hardest.

10	Diamond
9	Corundum
8	Topaz
7	Quartz
6	Feldspar
5	Apatite
4	Fluorite
3	Calcite
2	Gypsum
1	Talc

Hardness Testing is covered in the OUTCOME 4.

TOUGHNESS AND BRITTLENESS
Toughness is about how difficult it is to beak a material. Some materials are very strong but break easily. These are brittle like glass and cast iron. Other materials are not very strong but take a lot of energy and effort to part. Some polymers (plastics) are like this. Toughness is determined by measuring the energy needed to fracture a specimen. This is done in special test machines that use a swinging hammer to hit the specimen. The test also shows how susceptible the material is to cracking by putting a small notch in the specimen for the crack to start from.
Notched bar tests are covered in outcome 4.

SELF ASSESSMENT EXERCISE No. 2

1. What is the mechanical property of lead that makes it suitable for use as flashing on roofs?

2. What is the mechanical property of copper that makes it suitable for making into electric wires and water or gas pipes?

3. What is the mechanical property of steel that makes it suitable for structural components such as steel joists?

4. Why is cast iron suitable for making structural columns but not beams?

5. Two metals A and B are formed into identical short lengths of wire.

   Metal A can be stretched until it breaks but can be bent back and forth many times before it breaks.

   Metal B requires much more force to stretch it until it breaks and it does not stretch much. It is easily broken by bending once.

   Which metal is the most ductile?
   Which metal is the most brittle?
   Which metal has the greatest tensile strength?
   Which metal is the toughest?

6. What is the property of industrial diamonds that makes them so suited to make special grinding wheels?

3. THE AFFECT OF PROCESSING and MANIPULATION ON METALS

When a metal solidifies grains or crystals are formed. The grains may be small, large or long depending on how quickly the material is cooled and what happened to it subsequently. If the metal is maintained at a substantially higher temperature for a long period of time, the crystals will consume each other and fewer but larger crystals are obtained. This is called ***GRAIN GROWTH***. The grain size and direction can be changed by deforming the metal in the cold or hot state and this affects many mechanical properties such as hardness, strength and ductility. Heat treatment will also affect the grain and hence properties. In general slow cooling allows large crystals to form but rapid cooling promotes small crystals.

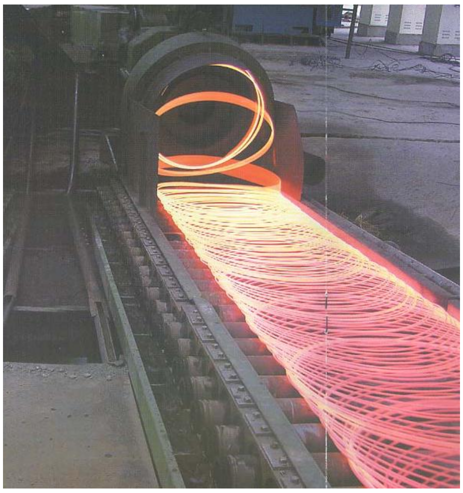
MANIPULATIVE PROCESSES

The following describes the various ways of producing metal products by manipulating the shape with plastic deformation.

COLD WORKING - Cold working a metal by rolling, coining, cold forging or drawing leaves the surface clean and bright and accurate dimensions can be produced. If the metal is cold worked, the material within the crystal becomes stressed (internal stresses) and the crystals are deformed. For example cold drawing produces long crystals. In order to get rid of these stresses and produce "normal" size crystals, the metal can be heated up to a temperature where it will re-crystallise. That is, new crystals will form and large ones will reduce in size. Cold working of metals change the properties quite dramatically. For example, cold rolling or drawing of carbon steels makes them stronger and harder. This is a process called ***WORK HARDENING***.

HOT WORKING - If the process is carried out at temperatures above the crystallisation temperature the process is called *HOT WORKING*. Most metals (but not all) can be shaped more easily when hot. Hot rolling, forging, extrusion and drawing is easier when done hot than doing it cold. The process produces oxide skin and scale on the material and producing an accurate dimension is not possible.

HOT ROLLING



This is used to produce sheets, bars and sections. If the rollers are cylindrical, sheet metal is produced. The hot slab is forced between rollers and gradually reduced in thickness until a sheet of metal is obtained. This may be cut into lengths (usually the thicker sheets) or coiled into cylinders as shown above (e.g. thin steel sheets for making car panels).

Steel wire is also produced this way. The steel starts as a round billet and passes along a line of rollers. At each stage the reduction speeds up the wire into the next roller. The wire comes of the last roller at very high speeds and is deflected into a circular drum so that it coils up. This product is then used for further drawing into rods or thin wire to be used for things like springs, screws, fencing and so on.

The rollers may be profiled to produce rectangular bars, and various shaped beams such as I sections, U sections, angle sections and T sections.

You can see hot steel rolling on this link.

http://www.youtube.com/watch?v=6xnKmt_gsLs&feature=player_embedded

COLD ROLLING

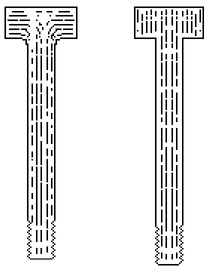
The process is similar to hot rolling but the metal is cold. The result is that the crystals are elongated in the direction of rolling and the surface is clean and smooth. The surface is harder and the product is stronger but less ductile. Cold working is more difficult that hot working.

FORGING This is usually performed on hot metals but cold forging is done when things like coins are stamped into a shape by squeezing it between two halves of a die. The dies may be a hammer and anvil and the operator must manipulate the position of the billet to produce the rough shape for finishing (for example large gun barrels).

This link has a good video of a forging process
http://www.brooksforgings.co.uk/?gclid=CL335snDiqoCFcRO4QodNHeSxw

DROP FORGING use a heavy weight dropped onto the billet. You can see the process at this link.
http://www.brooksforgings.co.uk/drop-forging.asp

Hot working, especially rolling, allows the metal to re-crystallise as it is it is produced. This means that expensive heat treatment after may not be needed. The material produced is tougher and more ductile. Hot working aligns the grains in a particular direction giving it a fibrous property. This may be used to advantage. Forging in particular makes use of aligning the grains to give maximum strength in the required direction. The diagram illustrates how the head of a bolt is formed by forging to change the direction of the grain. The right hand diagram shows the result of machining the head leaving a weakness at the corner.



Engine crankshafts are forged to produce optimal grain flow in a similar manner. These can also be cast. Look at this video.
http://www.youtube.com/watch?v=VxmbGBx0Ybg

Other products produced by forging are typically spanners, socket sets, garden tools, golf clubs, pipe line valve parts, pins and screws.

DRAWING

In this process, a metal billet is pulled through a die. The hole in the die has the shape of the finished section. This process is used to produce copper wire, seamless steel or copper tubing and so on.

Cold drawing produces work hardening and it may be necessary to anneal the metal at some stage.

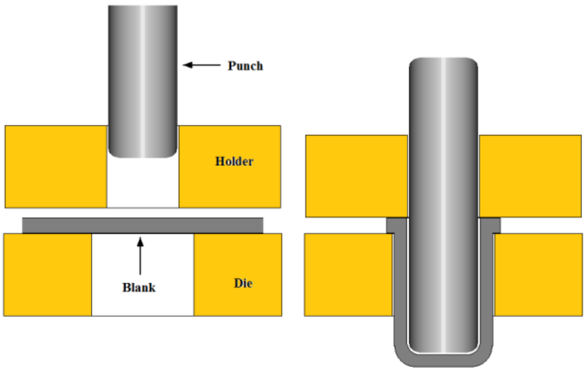
Cold drawing used on steel allows precise and complex sections to be produced. After careful pre-treatment and de-scaling, the special profile bars are drawn through a forming die up to three or four times. Special profiles can be produced that offer the same precision achieved by machining but without the waste.

The advantages include:

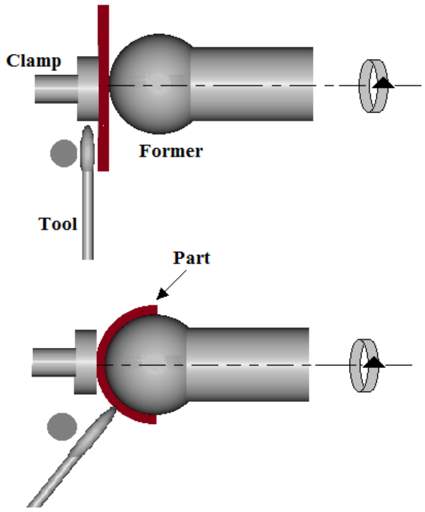
- Smooth and scale-free surface
- Sharp edges
- Uninterrupted grain orientation
- Increased tensile strength and yield point

Applications include many cold drawn steel shapes such as both carbon and stainless steel fittings, various stainless steel shapes used in aerospace applications, linear motion and machinery applications. The economical advantages of using cold drawn stainless steel profiles are numerous.
This web site explains a lot about the manufacture of copper tubes by cold drawing.
http://www.copper.org/publications/newsletters/innovations/how/howdo_tube.html
This link shows how copper wire is drawn and annealed.
http://www.youtube.com/watch?v=Y2YeENgabmY

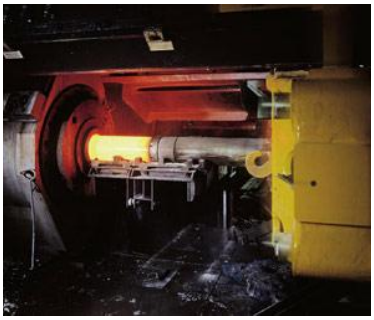
DEEP DRAWING is a term used to describe the process of forcing a sheet material into a cup shape as shown below. The metal is drawn into the die by the punch.
More complicated shapes are made in several stages and using external and internal dies in a process called PRESSING. This link shows a video of such a process.
http://www.youtube.com/watch?v=UClyNf6P_GM&feature=related



SPINNING
In this process the blank is held against the former and the whole assembly is spun. The blank is the forced into the shape of the former by forcing a forming tool against it. This method is used to produce aluminium satellite dishes, cooking pans and so on. The process is not best suited to large volume production.
You can see the process on this link
http://www.youtube.com/watch?v=um-biLfru-c&feature=related
This link shows a related process for making alloy car wheels.
http://www.youtube.com/watch?v=bzFzgtwvWZs



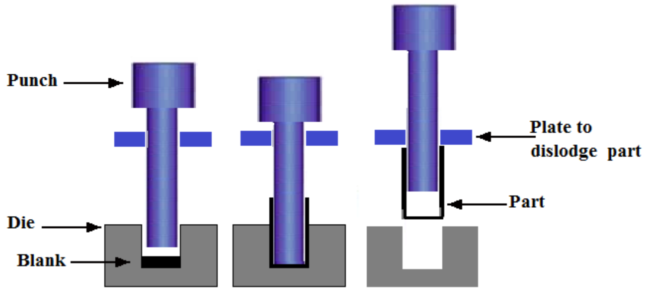
EXTRUSION
Squeezing toothpaste from a tube is an example of extrusion. Under stress, ductile metal will flow and in industry a metal billet is forced through a die from behind by a powerful hydraulic ram. The die has the shape of the section required. This method is used to produce aluminium sections and quite complicated shapes may be produced this way.



Hot Steel may be extruded as shown. The heated billet is pushed through a die into a profile bar. The advantages of extrusion over hot rolling, forging or machining are that it produces complex shapes even using metals which are difficult to form such as stainless steel and small batches can be produced economically.
The video on this link shows a steel tube being extruded over an internal die to make it into a large elbow.
http://www.youtube.com/watch?v=ny9PLxbRM7A
This video shows how aluminium tube is extruded.
http://www.youtube.com/watch?v=QKAg1yMZIpY&feature=related

IMPACT EXTRUSION

This process is similar to deep drawing but the blank is hit so fast with the punch that it flows plastically to mould itself into the shape formed between the die and punch. Materials best suited for this process are aluminium, lead and tin. Drink cans and battery cases are made this way.



You can see a video of the process at this link.
http://www.youtube.com/watch?v=zMhVPId-pRA

If the process is done more slowly, it might be called extrusion as shown on this link. http://www.youtube.com/watch?v=9mQ2ic-kDlk

SELF ASSESSMENT EXERCISE No. 3

1. Which hot metal working process would most likely be used to produce seamless steel pipes of large diameter? Give your reasons.

2. Which process would you choose to make a small number of circular copper bowls? Give your reasons.

3. Which process would you choose to make large number of aluminium drink cans? Give your reasons.

4. Steel hydraulic tubes must withstand very high internal pressure and must be accurate made with a good smooth surface finish. Which manufacturing process would be best?

5. Why is hot forging highly suitable for producing engine crankshafts?

6. Name the process by which large quantities of steel car panels (e.g. doors and wings) produced and what form the steel has prior to processing?

7. If you had to machine steel bar or rod in a lathe what difference would you expect to find between hot and cold rolled steel?

8. What is the process most likely to be used to produce aluminium sections with accurate dimensions?

9. Cold drawn copper wire is usually annealed after it is made. What is the reason for this?

LIQUID CASTING AND MOULDING

Many materials, especially metals, are suitable for casting by pouring the liquid metal into a mould and allowing it to solidify. The product has the shape of the mould and this may be the shape of a component which will need machining to complete it (for example an engine block) or an ingot for further processing such as rolling or drawing.

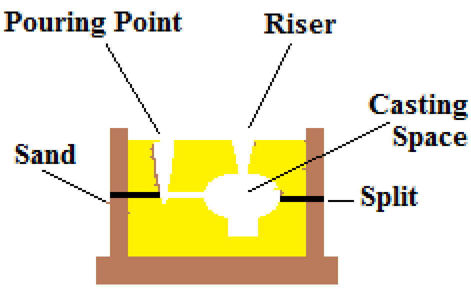
When the metal cools it contracts and the final product is smaller than the mould. This must be taken into account in the design.

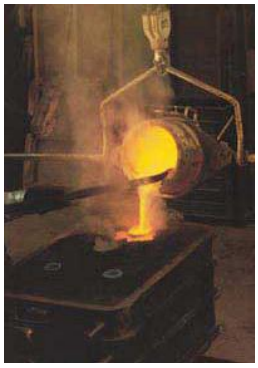
The mould produces rapid cooling at the surface and slower cooling in the core. This produces different grain structure and the casting may be very hard on the outside. Rapid cooling produces fine crystal grains. Here are some cast components.

There are many different ways of casting.

SAND CASTING

Sand casting is commonly used with cast iron, cast steel, aluminium alloy and brass. Heavy components such as an engine block would be cast in a split mould with sand in it. The shape of the component is made in the sand with a wooden blank. Risers allow the gasses produced to escape and provide a head of metal to take up the shrinkage. Without this, the casting would contain holes and defects.





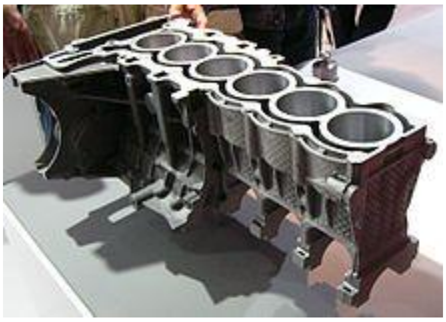
Sand casting is an expensive method and not ideally suited for large quantity production. You can see a video at this link. http://www.youtube.com/watch?v=dlQ54WATvzA

CENTRIFUGAL CASTING

This is similar to die casting. Several moulds are connected to one feed point and the whole assembly is rotated so that the liquid metal is forced into the moulds. This method is especially useful for shapes such as rims or tubes. Gear blanks are often produced this way. You can see the process on this link.
http://www.youtube.com/watch?v=3qKGx_AxHp0

DIE CASTING

Die casting is an efficient, economical process used for high-speed production of dimensionally accurate complex shapes. Little or no machining is required and thousands of identical castings can be produced before the mould wears out. Die castings uses a metal mould. The molten metal may be fed in by gravity as with sand casting or forced in under pressure. If the shape is complex, the pressure injection is the best to ensure all the cavities are filled. Often several moulds are connected to one feed point. The moulds are expensive to produce but this is offset by the higher rate of production achieved. The rapid cooling produces a good surface finish with a pleasing appearance. Good size tolerance is obtained. The best metals are ones with a high degree of fluidity such as zinc, copper, aluminium and magnesium with their alloys are also common.



You can see a video description of die casting at this link
http://www.youtube.com/watch?v=W6VgCaRozq8
You can see a video of real machines in action here.
http://www.youtube.com/watch?v=FEbJFbN4PfA

INVESTMENT CASTING

In this process, wax shapes are first made in a metal mould. The shape is then coated with a ceramic material. The wax is melted leaving a ceramic mould. After the metal is poured, the mould is broken to release the casting. The advantage of this is that metals with a very high melting temperature may be cast (e.g. turbine blades). These metals would destroy ordinary die casting moulds very quickly. Excellent dimensional tolerance is produced. Shown are some components made this way.
You can see the casting process on this link.
http://www.youtube.com/watch?v=BX8w-GUPz1w

POWDER TECHNIQUES

In this process, metal powder is poured into the mould and pressed with a die into the required shape. The powder is heated and pressurised so that the particles fuse. The structure produced is porous because granules do not melt completely but become sintered leaving gaps between them. The end product may a course sinter or a fine sinter. Bronze bearing bushes which retain lubricants in the porous structure are produced this way. Steel components such as shaft couplings are made this way. Very hard materials such as tungsten carbide may be formed into cutting tool tips by this method.

<u>SELF ASSESSMENT EXERCISE No. 4</u>

1. Find out and name three things made by centrifugal casting and three metals that can be cast this way.

2. What are the advantages and disadvantages of using the investment casting process to make things?

3. Find and name 3 things that are made by die casting and state the metals used.

4. Find and name 2 things made by sand casting with cast iron.

MACHINING

Machining processes are not covered in depth here. Machining processes involve the removal of material from a bar, casting, plate or billet to form the finished shape. This involves turning, milling, drilling, grinding and so on. The advantage of machining is that it produces high dimensional tolerance and surface finish which cannot be obtained by other methods. It involves material wastage and high cost of tooling and setting. Modern machine tools are computer controlled and can carry out many complex operations in the same machine. The cutting tool or the workpiece may be moved relative to each other.
Video of CNC Milling http://www.youtube.com/watch?v=Wk2VYwCIcZE

GRINDING is conducted to produce accurate dimensions and a good surface finish. A cylindrical grinder rotates the workpiece against the grinding wheel. Surface grinders traverse the grinding wheel over the workpiece to produce a flat surface. The grinding wheel is made of hard ceramic material and there are many types depending on the material to be ground and the surface finish required. Modern CNC grinders move the small grinding head around the component.

Surface Grinder on Left, Cylindrical Grinder on Right

Video of CNC grinding at this link http://www.youtube.com/watch?v=ROKJhTX_VTQ

SELF ASSESSMENT EXERCISE No. 5

1. If a steel component can be made by die casting or by machining it from a billet. Which would be the best to use if only 5 parts are required and which if 5000 parts are required? Explain your reasoning.

2. When a small quantity of components is ordered from a manufacturer who makes them on a CNC machine, they are often allocated a "minimum batch number". What does this mean and why is it used?

3. Find out and describe the meaning of "honing" in materials removal and explain why it is used.

4. Find out and state three reasons for using cylindrical grinding in the manufacture of components.

4. PROCESSING NON METALS

POLYMERS

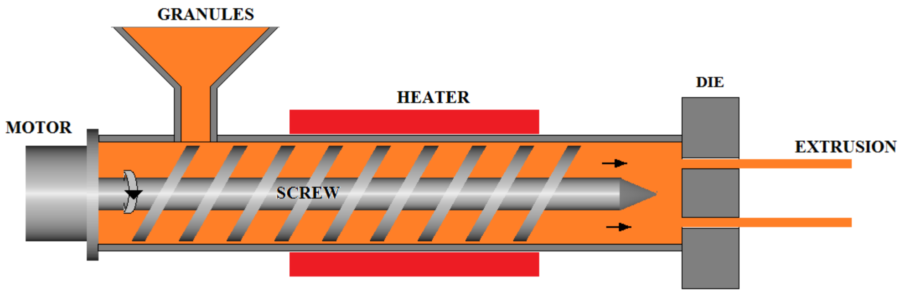
Most of the shaping processes described apply to metals but polymers may be moulded or machined depending upon their mechanical and thermal properties. You may recall that a thermoplastic may be re-melted over and over but a thermosetting plastic can only be melted once.

LIST OF THERMOPLASTICS

Acrylonitrile butadiene styrene (ABS)
Acrylic
Celluloid
Cellulose acetate
Ethylene vinyl acetate (EVA)
Ethylene vinyl alcohol (EVAL)
Fluoroplastics (PTFEs, including FEP, PFA, CTFE, ECTFE, ETFE)
Ionomers
Liquid Crystal Polymer (LCP)
Polyacetal (POM or Acetal)
Polyacrylates (Acrylic)
Polyacrylonitrile (PAN or Acrylonitrile)
Polyamide (PA or Nylon)
Polyamide-imide (PAI)
Polyaryletherketone (PAEK or Ketone)
Polybutadiene (PBD)
Polybutylene (PB)
Polybutylene terephthalate (PBT)
Polyethylene terephthalate (PET)
Polycyclohexylene dimethylene terephthalate (PCT)
Polycarbonate (PC)
Polyketone (PK)
Polyester
Polyethylene/Polythene/Polyethene
Polyether Block Amide (PEBA)
Polyetheretherketone (PEEK)
Polyetherimide (PEI)
Polyethersulfone (PES)- see Polysulfone
Polyethylenechlorinates (PEC)
Polyimide (PI)
Polylactic acid (PLA)
Polymethylpentene (PMP)
Polyphenylene oxide (PPO)
Polyphenylene sulfide (PPS)
Polyphthalamide (PPA)
Polypropylene (PP)
Polystyrene (PS)
Polysulfone (PSU)
Polyvinyl chloride (PVC)
Spectralon

Thermoplastics are often melted and extruded in a screw extruder as shown. Care has to be taken to ensure the plastic is at the correct temperature and pressure for the process.

Extrusion is a process of forcing molten plastic through a die to create finished sections and tubes. Commonly a screw extruder is used. The granules are fed into the screw and rotation forces them forward. The heater melts the granules and the molten plastic is continuously extruded out of the end.



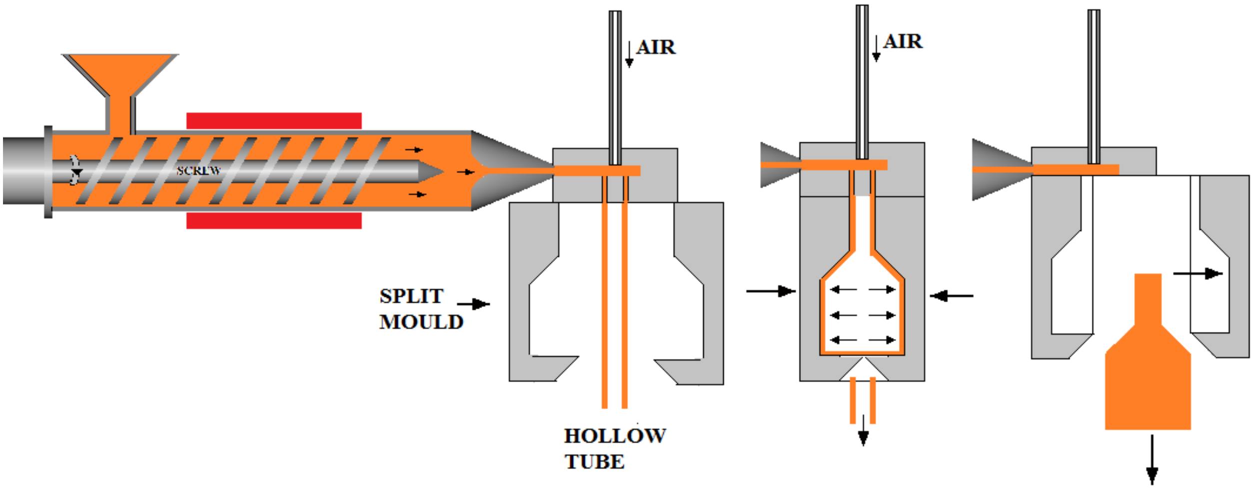
Blow moulding is a process where the molten plastic is inflated against the wall of the mould to form hollow plastic shapes such as bottles, jugs, buckets and tubes. Materials suitable for this are:

- Low Density Polyethylene (LDPE)
- High Density Polyethylene (HDPE)
- Polyethylene Terephtalate (PET)
- Polypropylene (PP)
- Polyvinyl Chloride (PVC)

There are several variations on the basic process.

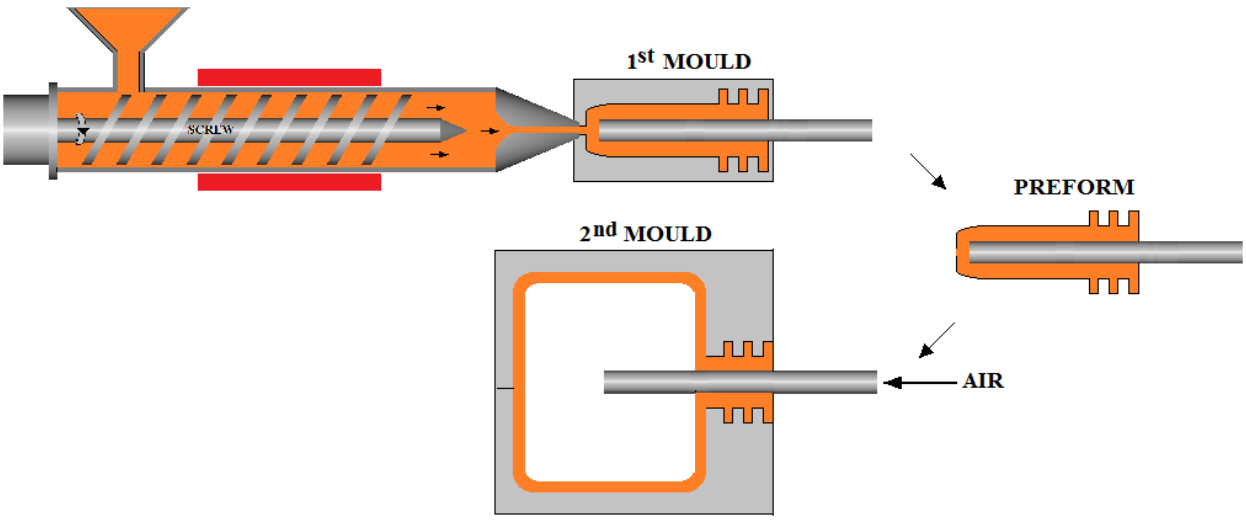
Extrusion blow moulding

The process begins with melting down the plastic and forming a hollow tube. The tube-like piece of plastic is called a preform or parison. The parison is then clamped into a split mould and air is forced into it. The air pressure expands the plastic against the wall of the mould. Once the plastic has cooled and hardened the mold opens up and the part is ejected.



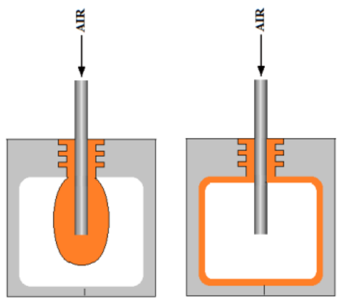
You can see an animated video of the process at this link.
http://www.bpf.co.uk/plastipedia/processes/extrusion_blow_moulding.aspx

Injection blow moulding is a similar process but precise amounts of plastic are injected into a split mould to create a preform on a pin. The preform on the pin is then indexed to a new mould where it is inflated and allowed to cool. The bottle is then indexed to the next station and ejected. This allows more precise detail in the neck and threaded area. The preforms can be stored and used later with reheating used to soften it. This process is suitable for bottles requiring clarity, and gas barrier properties needed for fizzy drinks.



You can see an animation of this process at these links.
http://people.bath.ac.uk/en3hl/blow.html
http://www.bpf.co.uk/plastipedia/processes/injection_stretch_blow_moulding.aspx

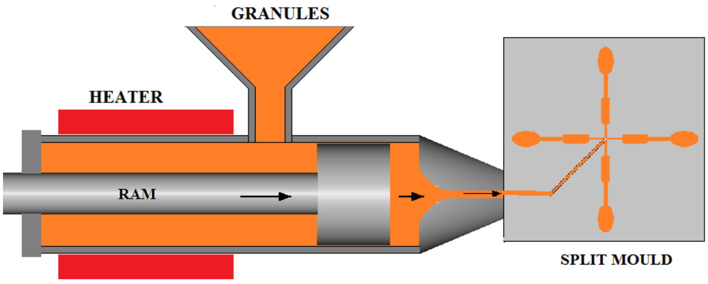
Injection Stretch blow moulding



The process is similar to the extrusion blow moulding but the plastic is injected into the mould and expanded in one process.

You can see an animation of this process at this link.
http://www.youtube.com/watch?v=V0FM8Ty8qYg

Injection moulding is used to produce a variety of solid components. The molten plastic is forced into the mould (often with a ram). The mould might create several identical parts at the same time.



Thermosets are moulded into more durable components. The raw material for thermosetting plastics is soft dough like material, liquid or soft uncured sheets called Sheet Moulding Compound (SMC). In order to form in the mould they have to be ***cured***. In many cases this involves heating them to 200°C or above to start an irreversible process to solidify and harden. The curing can be initiated by adding a chemical as in epoxy resin which only cures and sets when the two are mixed. In this form they are often used as adhesives and in particular for reinforced glass fibre products (GRP). Other things can trigger the curing process such as irradiation.

Thermosets are generally stronger than thermosetting plastics. Examples of thermosetting plastics are:

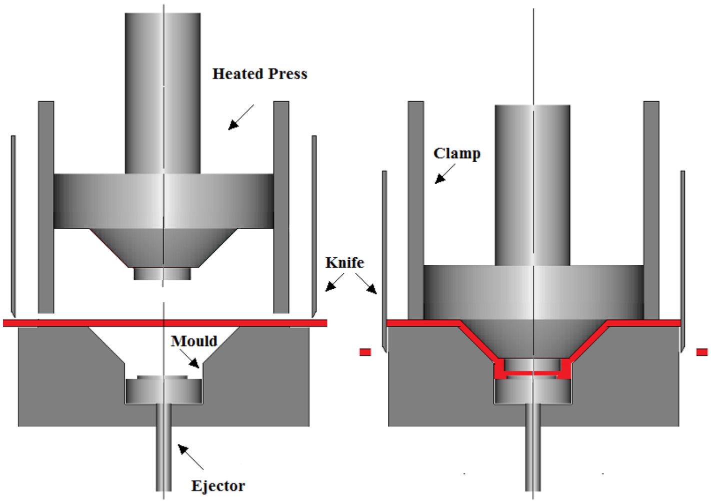
- Polyester fibreglass systems.
- Rubber (natural and Vulcanised).
- Bakelite - used in electrical insulators and plastic ware.
- Duroplast - a light but strong material, similar to Bakelite used for making car parts.
- Urea-formaldehyde foam (used in plywood, particleboard and medium-density fibreboard)
- Melamine resin (used on worktop surfaces and furniture).
- Epoxy Resin – used in GRP structures.
- Polyimides used in printed circuit boards and in body parts of modern airplanes.
- Cyanate Esters or Polycyanurates for electronics applications.

A few of the many products made with thermosets are:

- Wellingtons and rubber boots.
- Tires.
- Milk Crates.
- Bottle caps.
- Figurines.
- Gaming pieces (chess, counters etc.).
- Light Machinery parts (bearings, fan blades, gears etc).
- Car parts (bumpers, fuse oxes, filter cases etc.)
- Electrical parts (plugs, sockets etc.)
- Appliances (electric kettles etc.)
- Worktops.
- Furniture.

Parts are created by much the same method as described for thermoplastics with due care needed in providing the correct catalyst especially temperature and curing. Many parts are created using compression moulding.

Compression molding is a forming process in which a plastic material is placed directly into a heated metal mold, then is softened by the heat, and forced to conform to the shape of the mould as the mould closes. Materials used for compression moulding are either soft dough or SMC. When the plastic has cured and hardened, it is ejected from the mould.



You can see a video at this link.http://www.youtube.com/watch?v=xOzyaKDbE8s&NR=1

SELF ASSESSMENT EXERCISE No. 6

1. If thermosetting plastic is to be used in an injection mould, why should the mould be heated and not the injector?

2. Look up and list the properties of ABS that makes it suitable for making car bumpers (fenders)?

3. What would be the most likely way to manufacture Nylon Hair Combs? Give your reasons.

4. If similar ropes are made from Polypropylene and Nylon what difference would you expect in their performance.

5. Find out and explain why Polycarbonate is suited to making drinking cups and mugs.

6. Both ABS and Urea Formaldehyde are used to make electric plugs. One is thermosetting and one is a thermoplastic, find out which is which.

   Which one would be used to make a moulded one piece plug and which a two piece plug and why?

   Which is most likely to be used for applications where the plug may be accidentally hit e.g. by moving equipment about)?