Craft and Design

Materials and Processes

Designing for Manufacture

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HIGHER STILL

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Support Materials

Craft and Design
Designing for Manufacture
Section A: Materials

MATERIALS

In the initial stages of designing designers attempt to be as innovative and creative as possible. This divergent thinking results in a wide range of ideas and concepts. These are narrowed down towards the solution. At this stage the choice of materials and manufacturing processes play a significant role in deciding the final product. In order to explore these fully the designer requires to be aware of the properties of the materials and the manufacturing processes which are to be considered. The notes in this section give a general overview of various types of wood, metal and plastics to enable the designer to broaden his/her knowledge.

Timber

It takes many years for some trees to grow to a commercially viable size. As forests of the world are presently being depleted, many of the slow growing hardwoods are becoming very scarce. Modern forestry methods use fast growing conifer trees which can be harvested and replanted in a shorter space of time. With careful management it is possible to control the supply and demand of these softwood trees.

Selecting Timber

Timber suppliers usually stock pine, fir and spruce, the softwoods commonly used for carpentry and joinery. These woods tend to be sold as *dimensioned* or *dressed* stock i.e. sawn or surface planed sections cut to standard sizes. Most hardwoods tend to be sold as boards of random width and length but some woods such as mahogany, teak or oak can be bought as dimension stock. The selection of a particular wood for a design is quite important. Wood is a product of nature, therefore each piece is unique. Each section of wood cut from a tree will be different. It could have the same strength and colour, but is unlikely to have the same grain pattern. It is this diversity of character, strength, colour and workability that makes this material so appealing to use. Selecting wood is therefore a process of balancing its appearance with strength, workability, pliability, weight, cost and availability.

When considering wood as a choice of material, the vast range available to the designer falls into three categories: softwoods, hardwoods and manufactured boards.

Hardwood

Hardwood comes from deciduous trees, i.e. trees which loose their leaves. These trees also tend to be slow growing which makes their wood more expensive. Hardwoods tend to be more durable than softwoods and offer a greater choice of texture and colour. Unfortunately, the indiscriminate destruction of the world's rainforests is leading to a severe shortage of tropical hardwoods again adding to the expensive nature of this material. The following examples detail some of the more widely used hardwoods:

Name	Characteristics	Uses
Beech	Straight grained wood. Fine even texture. Whitish brown turning to yellowish brown on exposure.	Cabinet making, bent wood furniture, interior joinery, veneer, turnery, plywood.
Oak	Straight grained. Course texture. Pinkish red.	Furniture, flooring, boat building, veneer.
Ash	Straight grained. Coarse texture. Whitish to pale brown in colour.	Sports equipment, tool handles, cabinet making, veneer, furniture.
Mahogany	Straight or interlocking grain. Medium texture. Reddish brown to deep red.	Interior paneling, boat planking, carving, pianos, veneer.
Teak	Straight or wavy grained. Course uneven texture with oily feel. Golden to darker brown. Very expensive.	Interior and exterior joinery, garden furniture, veneer.
Walnut	Straight to wavy grain. Grey brown with darker streaks.	Furniture, gunstocks, musical instruments, carving, veneer.
Balsa	Open straight grain. Very pale beige to pinkish colour. Softest and lightest commercial hardwood.	Insulation, buoyancy aids, model-making, packaging.

Note: Although these definitions of hardwoods and softwoods are correct there is always the odd exception. In the case of hardwoods for example, most broadleaf trees grow in temperate zones and are deciduous but some have developed into evergreens.

Softwood

Softwood comes from coniferous trees, i.e. evergreen trees with thin needle-like leaves. These trees tend to grow quickly which makes their wood cheaper to use commercially. Softwoods are easily identified by their light colour and open grain pattern. The following examples detail some of the more widely used softwoods.

Name	Characteristics	Uses
Scots Pine	Light coloured, resinous. White yellow to yellow brown.	Furniture, construction work, joinery.
Red Cedar	Relatively soft aromatic timber. Reddish brown to silver grey after long exposure to weathering.	Shingles, exterior boarding and cladding, greenhouses, sheds and beehives.
Parana Pine	Straight grain. Even texture. Light to dark brown with red streaks.	Joinery, furniture, turnery.
Spruce (white wood)	Straight grain. Even texture. Almost white to pale brown.	Construction, joinery, boxes, plywood, piano soundboards, violin bellies, masts and spars.

Manufactured Boards

Manufactured boards are a relatively new type of material and are being used more and more in both home and industry. They have several advantages over natural timbers. They have strength in all directions due to criss-crossing of grain in each layer, are more resistant to changes in temperature and humidity and board sizes are greatly increased. Manufacturers are constantly developing these materials to improve their quality, ease of working and use of raw materials. This development has given rise to a wide range of boards available. Manufactured boards roughly fall into three categories: laminated boards, fibreboards and particle boards.

Laminated Boards

such as plywoods are constructed from thin sheets of wood bonded in layers to form a strong, stable board. The grain of each alternate sheet is laid at right angles to the next. This construction produces a stable, warp resisting board. Most plywoods have an odd number of veneers to give a balanced construction, the minimum being three, but four and six ply is also available for use in structural work. Plywood is available in a range of sizes.

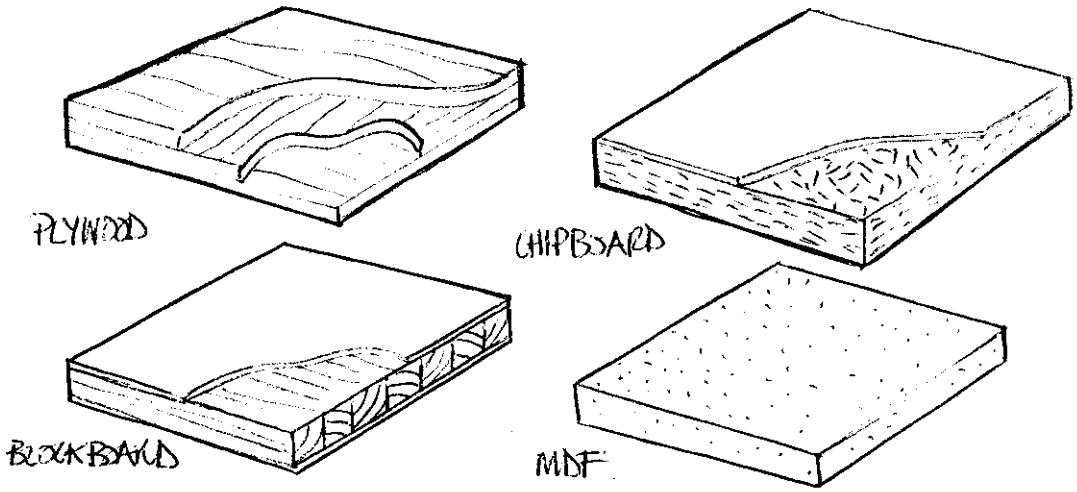
Blockboard differs from plywood given that the core is made from square blocks of wood laminated with a layer of ply on each side.

Fibreboards

are constructed from wood that has been reduced to a fibrous state and added to a bonding adhesive then compressed into boards. Boards of various density are produced depending on the pressure applied and bonding material used.

Particle boards

are constructed from flakes or chips of wood bonded together under pressure. Depending on the size of the wood particles various types of board are produced. Chipboard is most commonly used although it will swell if exposed to moisture and will not recover. Moisture resistant types are available. Can be veneered for internal structures.



The following table shows some of the most commonly used manufactured boards.

Name	Properties & Characteristics	Uses
Medium Density Fiberboard (M.D.F.) *	Two smooth surfaces. High strength. Excellent edge quality.	Furniture with intricately shaped parts or large smooth surfaces, carcass construction.
Plywood	An odd number of veneers is laid at 90° to each other, with surface parallel to grain.	Interior joinery, carcass construction. Decorative ply is mainly used for paneling.
Blockboard	Timber strips laid parallel with veneers glued either side with their grain running crosswise.	Shelving and worktops.
Chipboard	Wood chips mixed with bonding mixture to create large flat boards. Surface and strength depends on chip particle size.	Furniture, flooring, flat roof construction, kitchens and bathrooms.
Hardboard	Standard hardboard has one smooth face and the other embossed.	Wall and ceiling linings, paneling, partitions, shop fitting display and exhibition work.
Veneer	Thin sheets of wood cut from a log for constructional or decorative purposes. Wide variety. Usually glued to one of the other types of board before use.	Furniture restoration, Wall paneling, furniture making, violin backs.

Question
Advances in man made boards, where additives have been introduced, have dramatically expanded the range of options available to designers.
*(a) Name **three** of these man made boards.*
*(b) Name one component manufactured from **each** material.*

Metal

Metals can either be pure material extracted from ore deposits found buried in the earth's surface or made from a mixture of two or more metals combined with other elements. The latter are called *alloys*. Pure metals are also split into two categories, *ferrous* and *non-ferrous* metals.

Metals are an extremely versatile material in the world of design. The huge variety of metals and alloys can be used in many applications from jewelry to engine parts. Each type of material has its own properties which dictate the suitability of the material to its purpose. Such properties are:

Elasticity - the materials ability to return to shape after deformation.
Toughness - the materials ability to withstand sudden loading.
Brittleness - lack of elasticity and toughness, easily snapped.
Malleability - ability to be hammered into shape without fracturing.
Hardness - resistance to wear or indentation.
Ductility - ability to be stretched to a reduced cross section.

Ferrous Metals

These metals contain iron and tend to rust in moist conditions. Almost all ferrous metals are magnetic. Pure iron is difficult to produce and not often used nowadays.

Name	Properties	Uses
Cast Iron	Iron + 3.5% carbon. Brittle with a hard skin. Casts well.	Machine tools, vices.
Mild steel	Iron + up to 0.35% carbon. Malleable, ductile with a very uniform texture.	Nuts, bolts, screws, tubes, small non-cutting tools.
High carbon steel	Iron + up to 1.5% carbon. Malleable & ductile. Can be hardened and tempered.	Cutting tools, files, drills, saws, taps & dies, knives, scribers, lathe tools, hammer heads.

Non-Ferrous Metals

These metals do not contain iron therefore will withstand moist conditions. Non-ferrous metals are not magnetic.

Name	Properties	Use
Aluminum	Pure metal from Bauxite ore. Strength to weight ratio good. Casts easily.	Window frames, food packaging, kitchen utensils.
Copper	Tough, ductile and malleable. Good conductor. Expensive.	Central heating pipes, electric wires and cables, jewelry.
Tin	Heavy and soft material with a low melting point.	Surface coating on sheet steel.
Lead	Very heavy, soft, weak, ductile and malleable. Low melting point, can be cast.	Roof flashing, plumbing, solder.
Zinc	Weak and difficult to work. Used extensively in alloys.	Surface coating on steel (galvanized). Dustbins, corrugated sheets, castings.

Alloys

An alloy is a mixture of two or more metals formed together with other elements such as copper and zinc to create new materials. These new materials tend to have more desirable qualities than pure metals.

Name	Composition	Properties	Uses
Stainless steel	Iron & carbon + Chromium + Nickel + Magnesium	Ferrous. Hard and tough. Corrosion and wear resistant.	Cutlery, sink units, dishes, teapots, boat fittings.
High speed steel	Medium carbon steel + tungsten + chromium + vanadium.	Ferrous. Very hard. Excellent heat resistance.	Tool bits, drills, lathe cutting tools.
Brass	Copper + zinc	Non-ferrous. Corrosion resistant, hard. Casts well, work hardens. Easily joined, polishes well, good conductor.	Taps, decorative items, boat fittings, casting.
Bronze	Copper + Tin + zinc	Non-ferrous. Strong and tough. Wear and corrosion resistant.	Statues, water fittings, coins.
Duralamin	Copper + manganese + magnesium	Non-ferrous. Very good strength to weight ratio. Age hardens. Machines and finishes well.	Aircraft parts.

Question

Figure 1 *shows a drawing of a Chinese cooking wok, designed for high temperature, fast stir-fry cooking.*

The body of the wok is manufactured from thin gauge mild steel.

Figure 2 *shows a drawing of a cast iron saucepan designed for low temperature, slow cooking.*

For each product, explain how the cooking requirements led to:

(i) the choice of material;

(ii) the method of construction.

Figure 1

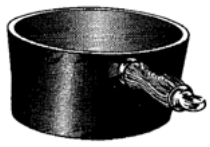


Figure 2

Plastics

Plastics are synthetic materials produced from refined oil products. From various manufacturing processes a large selection of plastics are produced. Plastics provide a versatile material for designers to work with as they are extremely suitable for mass production and can be made to suit a wide range of applications by simply altering their chemical structure. There are two main categories of plastics, *thermoplastics* and *thermosetting plastics.*

Thermoplastics

This type of plastic will soften on heating allowing it to be shaped and will set when cooled. This process can be repeated again and again. When reheated a thermoplastic will return to its original shape, this is called plastic memory.

Name	**Characteristics**	**Uses**
Polythene (Low density)	Good electrical insulator, Soft & flexible. Variety of colours.	Carrier bags, squeezy bottles, toys, detergent.
Polythene (High density)	Good chemical resistance. Stiff and hard. Variety of colours.	Buckets, bowls, milk crates.
Polyvinyl chloride (**uPVC**)	Weather resistant. Stiff, hard, tough & lightweight.	Pipes, guttering, curtain rails, window frames.
Polystyrene (a) conventional (b) expanded (c) Toughened	 (a) Light, hard, transparent, waterproof. (b) Light, buoyant, good insulator. (c) Good strength	 (a) Kit models, food containers. (b) Ceiling tiles, insulating boxes. (c) Toys, refrigerator linings.
Polyamide (**Nylon**)	Good chemical resistance. Hard, tough & rigid. Machines well.	Wheels, gears, machine parts.
Cellulose acetate	Tough, hard & stiff. Lightweight, Transparent.	Pen cases, Spectacle frames, photographic film.
Acrylic (Perspex)	Weather durable. Stiff & hard. Easily scratched. Variety of colours.	Shop signs, display stands.
Polypropolyene	Light, hard, impact resistant, can be sterilized.	Shampoo bottles, medical equipment, film.
ABS	High impact strength, scratch resistant, durable.	Telephones, toys, safety helmets, kitchen ware.

Thermosetting Plastics

This type of plastic can be softened with heat and shaped. Unlike thermoplastic, this material will set and cannot be reshaped.

Name	**Characteristics**	**Uses**
Epoxy Resin	Good chemical, heat and wear resistance.	Adhesives, surface coatings.
Melamine Formaldehyde	Stiff, hard & strong. Reasonably water resistant. Scratch, heat & stain resistant. Variety of colours.	Kitchen worktops, electrical insulation
Urea Formaldehyde	Stiff, hard, strong & brittle. Electrical insulator. Variety of light colours.	White electrical fittings, adhesives.
Polyester Resin	Stiff, hard & brittle. Heat and chemical resistant. Good electrical insulator.	Chair shells, car bodies, boats reinforced with glass (GRP).

Question

Developments in plastics have resulted in their use in furniture design, in place of traditional materials for:

(i) Construction
(ii) Surfaces
(iii) Upholstery
(iv) Fixtures and fittings

*For **each** of these show how designers have taken advantage of the design potential offered by plastics.*

Plastics Identification

Plastics can be identified through a variety of tests some of which are given in the tables shown. In general, most thermoplastics will cut cleanly, become pliable at 200 °C or less and if heating continues will melt to become a thick and sticky liquid. Thermosets will produce powdery fragments when cut with a knife and bubble and disintegrate before softening.

Name	**Does material cut with a sharp knife?**	**Does material bend at room temperature?**	**What happens in water?**	**Will material scratch with a fingernail?**
Polythene	Cuts cleanly	LD : Flexible HD : rigid	Floats	yes
Polyvinylchloride (PVC)	Cuts cleanly	Plasticised : flexible Rigid : stiff	Sinks	Plasticised : yes Rigid : no
Polystyrene	Fairly hard	Rigid	Sinks	No
Expanded polystyrene	Breaks into small fragments	Breaks	Buoyant	Yes
Nylon	Cuts reasonably cleanly	Rigid	Sinks	Yes
Acrylic	Fragments	Breaks	Sinks	No
Polypropelene	Cuts reasonably cleanly	Rigid	Floats	No
Melamine formaldehyde	Splinters	Very rigid	Sinks	No
Urea Formadehyde	Splinters	Very rigid	Sinks	No

The Effects of Burning Plastics

Name of material.	**Does material soften?**	**Does material ignite?**	**Colour of flame.**	**Nature of the smoke present.**	**Nature of the flame?**	**Does material continue to burn?**
Polythene	Yes	Easily	Blue with a yellow tip.	Small amount	Burning droplets which go out on surface contact. Smells of candle wax.	Yes
Polyvinylchloride (PVC)	Yes	Difficult	Yellow	White with heavy soot.	May drip. Smells of hydrochloric acid.	No
Polystyrene	Yes	Easily	Orange/ Yellow	Black with soot	Burning droplets. Smells sweet.	Yes
Expanded Polystyrene	No	Easily	Orange/ Yellow	Black with soot	Drips continue to burn. Smells sweet.	Yes
Nylon	No	Difficult	Blue with a yellow tip	Small amount	Melts to a liquid which drips carrying a flame. Smells like burning hair.	Yes
Acrylic	Yes	Easily	Yellow, blue base and clear edges	No smoke	Drips which continue to burn. Bubbles first. Smells strong, sweet and fruity.	Yes
Polypropylene	Yes	Easily	Yellow with a clear blue base	Small amount	Burning droplets which go out on surface contact. Smells like candle wax but unlike polythene.	Yes
Melamine Formaldehyde and Urea Formaldehyde	No	Difficult	Pale yellow, light blue green edges	Small amount	Swells and cracks, turns white at edges. Smells pungent and burning.	No

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Section B: Processes

PROCESSES

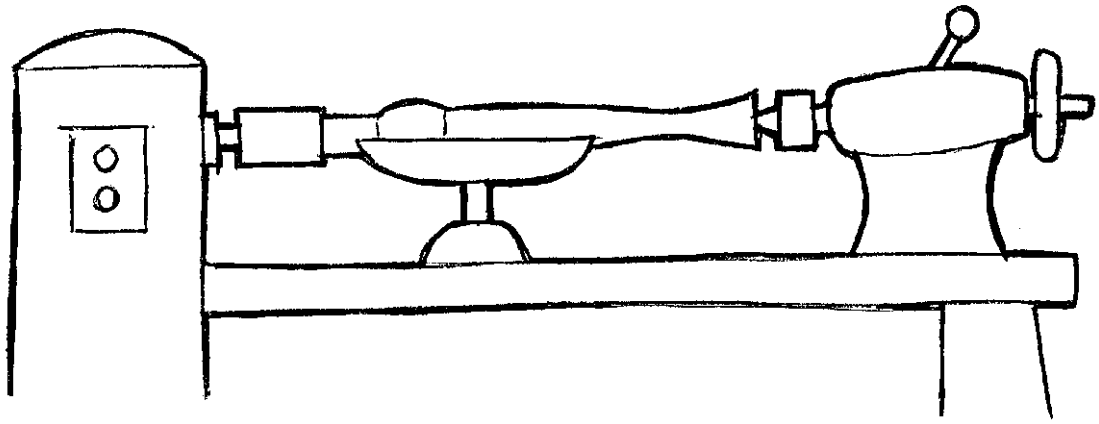
The first section of these notes has shown the vast array of materials available to the designer. The following notes are intended to show how these materials can be processed in industry to become useful objects.

Timber

Timber is a very versatile material and can be used to create a variety of shapes with the use of the power and machine tools. Many woodworking machines offer a fine degree of finish and accuracy that would be difficult to produce by hand. Powerful machinery makes light work of ripping, crosscutting and planing timber. Most machines are designed to make the cutting of identical components easy and precise.

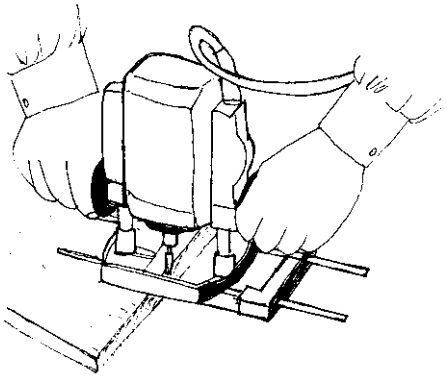
The Lathe

Wood turning is the process of forming round objects on a lathe. There are two methods of turning, *between centres* and *faceplate turning.* Turning between centres is used to produce long cylindrical items such as table legs. Turning with a faceplate is used to produce items such as bases or bowls. As the wood rotates, special cutting tools are used to create shape.



The Power Router

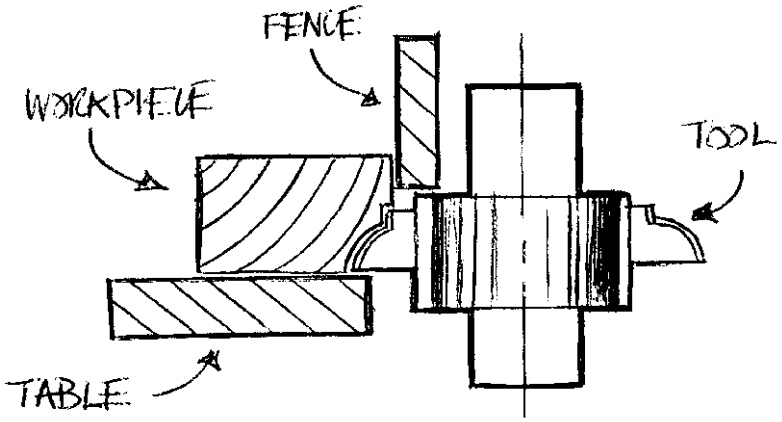
The power router has taken the place of a whole family of grooving, moulding and rebating planes. It is a very versatile addition to the workshop. It consists of a high speed electric motor in a lightweight plastic housing which insulates the user from contact with live components. A cutter is fitted directly below the motor housing fitted with a handle on each side. A wide variety of cutters can be fitted into the router which can be used for grooving and housing, rebating or moulding.



Spindle Moulding

Spindle moulders are mostly used for cutting mouldings and certain woodwork joints. The machine consists of a cutter block that rotates at high speed on a vertical spindle protruding through a hole in the worktable. Adjustable fences guide the work past the cutter block. A large variety of shaped cutting tools are available for spindle moulders. All woodworking machines need to be handled with care, but a spindle moulder can be particularly dangerous.

Special purpose spindle moulding machines are made for industry. The range of mouldings is vast and most timber merchants carry large stocks. Examples of mouldings include door and window frame section. Virtually any timber can be used for mouldings, but those with finer textures give smoother surfaces for final finishing. The properties of MDF make it especially suitable for mouldings that are usually finished by coating.

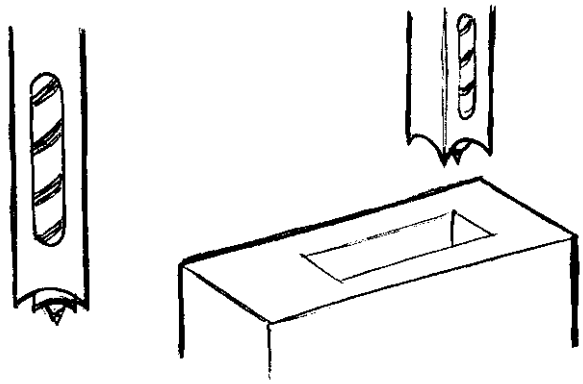


Mortising Machine

Heavy duty mortising machines are found in industrial workshops where cutting mortise and tenon joints is an integral part of the mass production process.

Hollow Chisel Mortiser

This machine has a special auger drill in the centre of a square, hollow chisel that has four cutting edges. When plunged into the workpiece it cuts a square hole. The drill cuts out the waste whilst the chisel squares off the corners. To cut a long, rectangular mortise the workpiece is slid sideways between each cutting.



Bandsaws

The bandsaw is an efficient, versatile machine whose main uses are handling large quantities of wood and shape cutting. It can cut thicker timber than the average circular saw and the thin blade means that wastage is minimal. The blade itself is a continuous loop of metal driven over two or three large wheels. A bandsaw can be used to cut outside curves but not inner curves without cutting through the material.

Jigsaws

The jigsaw is a very versatile tool. It will cut any man made board and rip or cross cut solid timber reasonably well. Its real advantage, however, is its ability to make curved cuts. When fitted with the appropriate blade the jigsaw will also cut sheet metal and plastics.

Fretsaws

Powered Fret saws are usually connected with lightweight craftwork and model making. A fret saw can be used to produce very accurate work as well as being able to cut very tight curves.

Plastics

Plastic materials come from manufacturers in many forms i.e. fine powders, granules, pellets, cubes, emulsions, viscous fluids and resins. These forms can be processed to produce workable plastics. These new forms of plastic material can then be used to produce useable items or components with the aid of machinery.

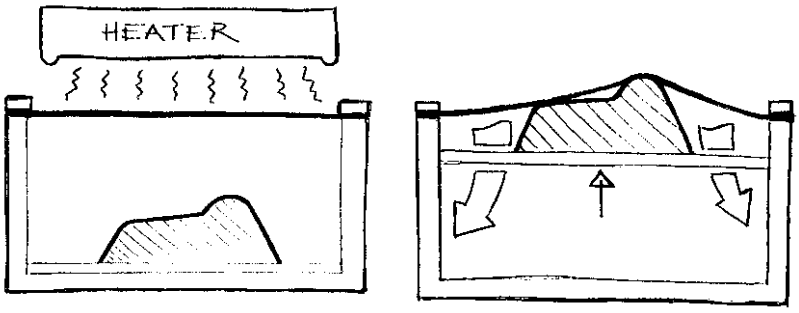
Vacuum Forming

This is the process of drawing a sheet of thermoplastic material which has been softened by heat over a mould using a vacuum force. Vacuum Forming is very useful for the production of identical mouldings. Examples of commercial products made in this way are margarine containers, egg boxes, chocolate box trays and various packaging item

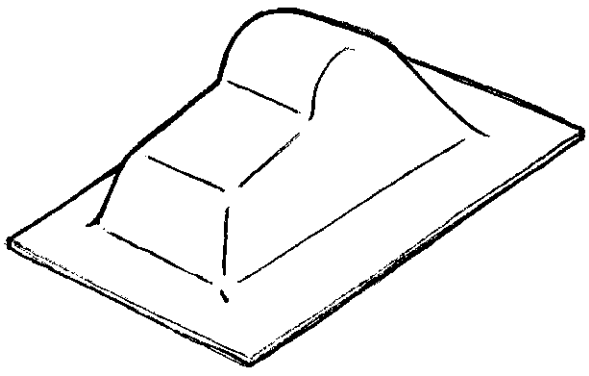
The Vacuum Forming Process

There are several designs of vacuum forming machine but they all work in a similar manner to the following:

1. The plastic sheet is clamped in a frame forming an air tight seal over a vacuum chamber.
2. A heater is placed above the sheet. The sheet is heated until is in the correct condition for forming (plasticity).



3. A lever is pulled which raises the platform, complete with the mould, inside the vacuum chamber. The mould is pushed into the softened sheet.
4. A pump is then switched on which removes all the air in the chamber and causes the plastic sheet to form tightly around the mould.
5. The sheet is unclamped and removed from the former and the mould is tapped out. Excess material is trimmed off the moulding.



Making Moulds

Moulds are normally manufactured from wood. To allow easy removal of the mould from the moulding it is usually tapered (all vertical sides are angled) with no undercuts. Deep moulds can cause problems such as thinning on the vertical surfaces when the material is drawn down or any excess plastic sticking together at the corners (webbing). Moulds must be very smooth as any rough surface will show through the thin plastic sheet.

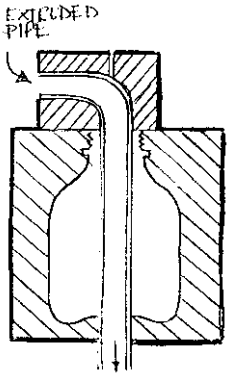
Blow Moulding

This is the process of shaping a heat softened sheet of thermoplastic by forcing it into a mould using compressed air which enters the mould via a narrow inlet. This process is used in the production of drinks and detergent bottles, toys and many types of container. Blow moulding is a fast process with very little waste and is able to be highly automated.

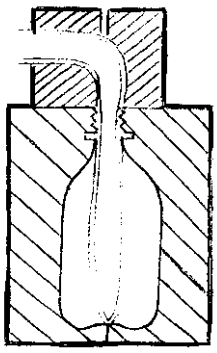
The Blow Moulding Process

The following process is the method used in industrial applications:

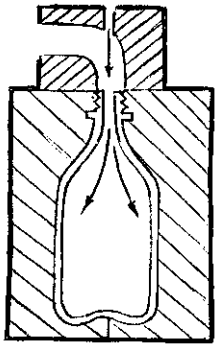
1. A hollow length of thermoplastic called a 'parison'(made by extrusion or ejection moulding) Is forced between two halves of a mould.



The mould is closed which seals the two ends of the parison, cutting it to the required length.



Compressed air is forced into the soft parison which causes it to inflate into the shape of the mould. The cold mould causes the plastic to cool on contact. The mould then re-opens, the blown shape is rejected and the process begins again.

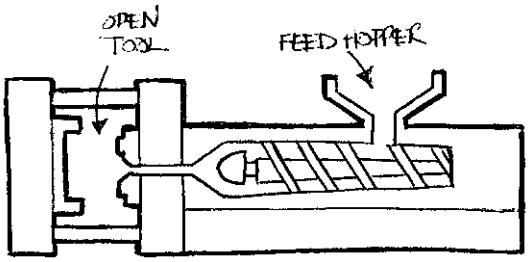


Injection Moulding

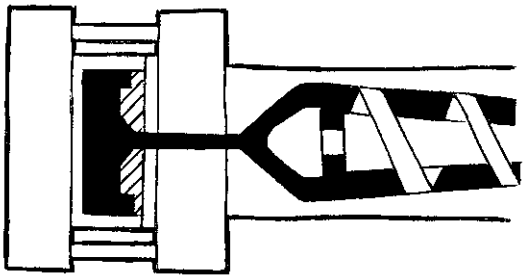
In this process a thermoplastic material in the form of granules is heat softened and injected into a mould where it is then cooled. When opened, a component is produced which has taken the exact shape of the mould. Injection moulding is one of the most important methods of producing plastic goods. Items such as buckets, telephones, golf tees and ball pens are produced in this way.

The Injection Moulding process

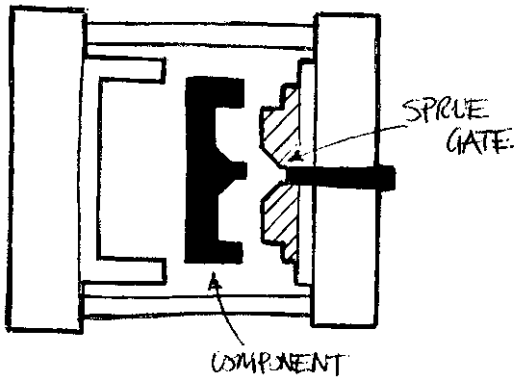
1. A large hopper is filled with thermoplastic granules feeds a rotating screw mechanism which transfers these granules to a heater.



2. The heater causes the granules to become softened (plasticised). The material in this state is then injected under pressure into a mould where it is then cooled.

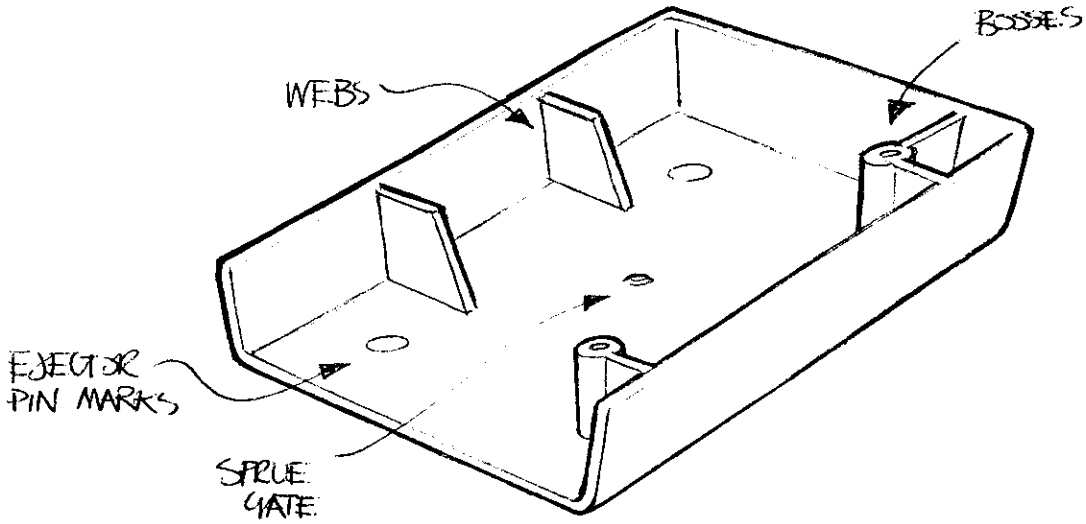


3. The mould is then opened automatically and the finished mould ejected. Injection moulded products are usually of such a high quality that they require no further finishing.



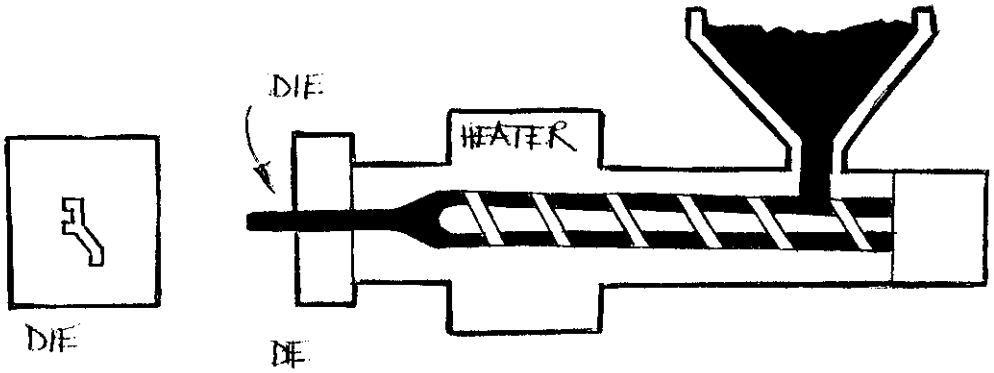
Design For Injection Moulding

Making moulds for this process is a highly skilled job therefore they tend to be very expensive. Very complex and textured components can be produced in this way. However, from one mould thousands of identical components can be produced very cheaply. There are a number of characteristics which indicate that a component has been made by this process. Firstly, a split line will be visible around the component, this is where the parts of the mould would separate. The sprue gate where the molten plastic enters the mould is also often visible. Finally ejection pins will leave small round marks, usually on the inside of the component.
Webs are also often used in injection moulded components to provide strength and to keep wall thickness similar.



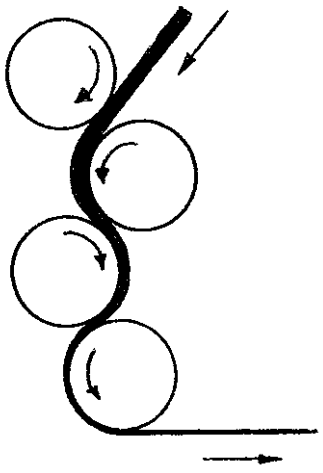
Extrusion

The process of extrusion is like squeezing toothpaste from a tube. Thermoplastic granules are plasticised by heat and forced through a shaped die which determines the shape of the product. The shape of the die may be very complex. The extruded material passes through a cooling unit to allow it to reharden. Extruded products will need further finishing at this stage to be transferred into useful items. Extrusion is used in the production of a great variety of products such as pipes and cables, fibers for fabrics, fluorescent light covers and curtain rails.



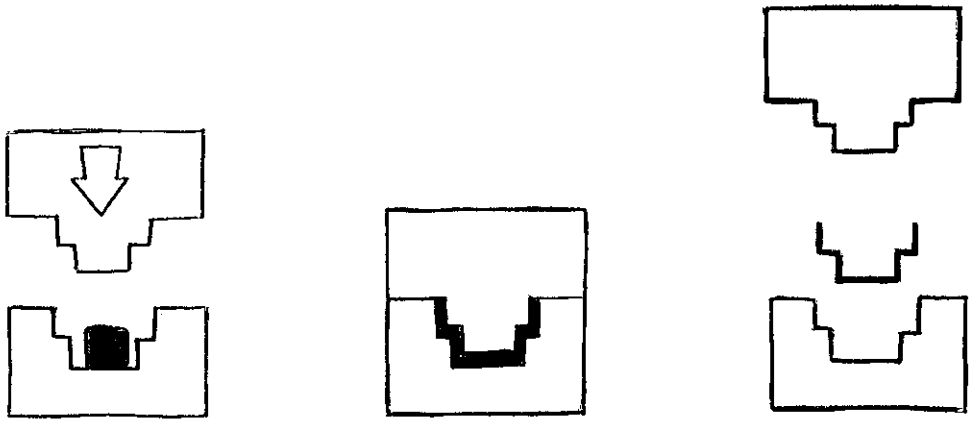
Calendering

A constant flow of heated thermoplastic is fed between a series of hot rollers which will compress it to a set thickness. The material is then passed through cooled rollers which will further compress the sheet to the required thickness. The material can be laminated with another material or imprinted with a design via a further roller. Calendering is used for a huge variety of applications such as vinyl coated wall coverings, waterproof materials, shampoo sachets and car seat covering.



Compression Moulding

This process is used to permanently shape thermosetting plastics such as phenol formaldehyde, urea formaldehyde and melamine formaldehyde. The plastic in pellet form is placed in a highly polished mould and subjected to heat and pressure. The heated material sets hard in the mould and is automatically ejected when ready. Compression Moulding is used for items which can resist temperature i.e. saucepan handles and for other everyday items such as plugs, wall sockets and toilet seats.



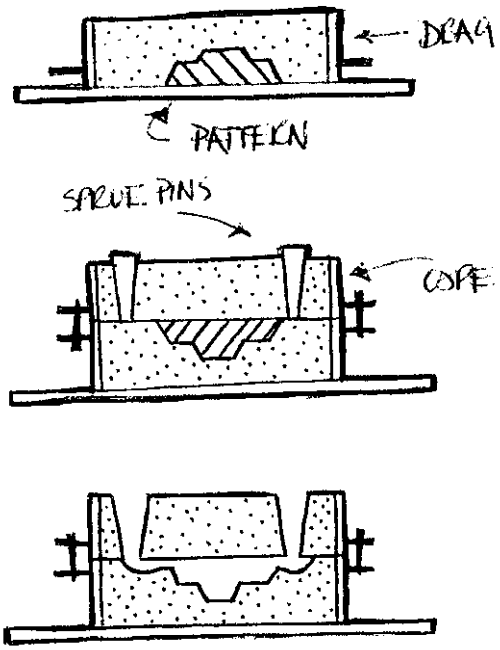
Metal

Metals have many properties that make them a versatile material for manufacturing. In the earlier section of these notes we looked at such properties as toughness. hardness, ductility and malleability. The following notes show how these properties can be utilized and processed to produce useful components.

Sand Casting

This process involves pouring molten metal into a mould and leaving it to harden. The mould is made in a flask which splits into two parts (cope and drag) which fit accurately together. A pattern is placed in the bottom half of the flask (drag) and oil soaked sand is packed around. The drag is then turned over and the cope attached. Sprue pins are now inserted and the sand is packed around before removing the pins. The flask is split and pattern removed leaving a cavity. The flask is then reassembled and ready to receive the molten metal. The molten material is poured in through one of the sprue pin holes (runner), fills the mould and exits along with any gases via the second hole (riser). When cooled the cast object can be removed from the flask.

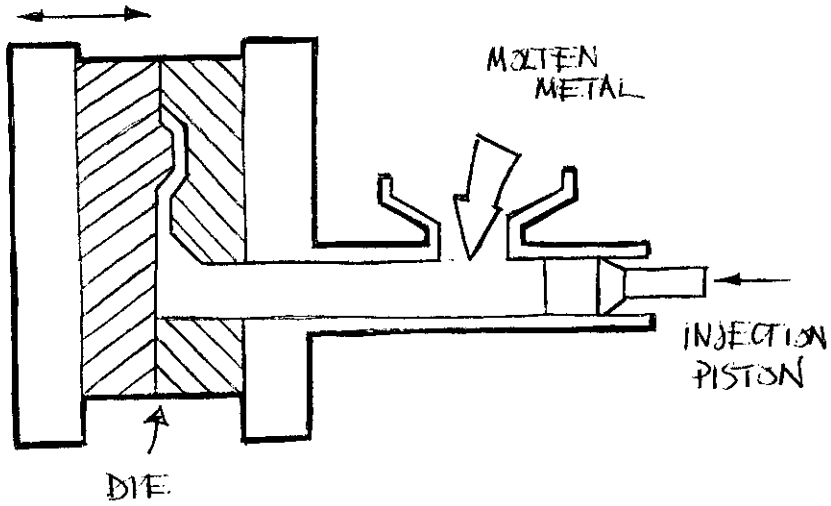
The patterns for this process are relatively cheap and easy to produce. The surface texture of the end product tends to be poor and may require further finishing. Casting does allow complex shapes to be produced that could not be produced in any other way. Casting is used in the manufacture of items such as engine parts, tools and decorative items.



Pressure Die Casting

In industry where large numbers of high quality castings need to be manufactured it becomes essential to make permanent high quality moulds. These moulds are known as dies and tend to be expensive to produce due to their complex nature and materials costs. These factors render die casting suitable for mass production where accuracy of shape, size and surface finish is important. Die casting is used to produce items such as toy cars, military models, car parts and camera bodies.

The process of pressure die casting involves forcing molten metal into a water cooled die through a system of sprues and runners. The metal solidifies very quickly and is removed with sprues and runners intact. Very little finishing is now required other than removal of the sprues and runners and any flashes that have been caused by leakage of material between the parts of the die.

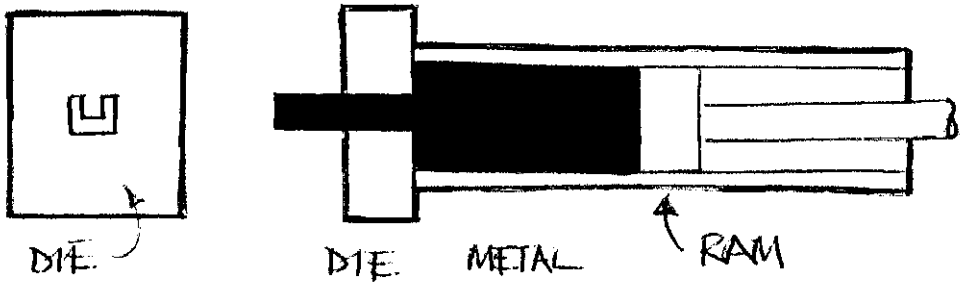


Extrusion

Extrusion of metal is similar to the process of extruding plastic. The heated metal is forced using a hydraulic ram through a shaped die to produce a continuous shape with a uniform cross section. The best materials for extrusion are copper and aluminium alloys as these can be extruded hot or cold. Cast iron and steel can also be extruded but with very high temperatures.

This is a fairly inexpensive process as most of the cost is involved in the machinery and the production of the dies. However the end products are of a high quality and require little extra finishing other than cleaning up and any drilling of holes necessary.

Examples of items produced by extrusion are aluminium window frames and curtain rails. Extruded sections are strong and lightweight and require no painting or maintenance. For these reasons British Telecom made their new phone booths from such sections.



Milling

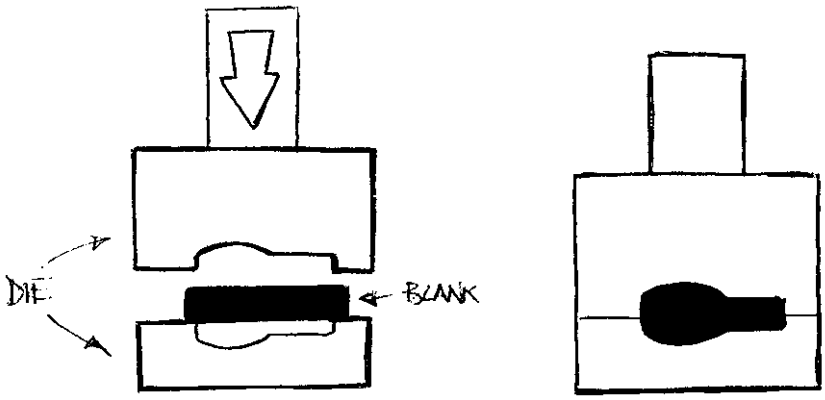
Milling machines are powerful pieces of equipment which use rotating multi toothed cutters to shape the material. There are two types of milling machine, horizontal and vertical. The machines are named by the position of the cutting tool in relation to the workpiece. Milling machines can be used as side and face cutters and can also be used to cut slots in the material.

Turning

Turning is the production of cylindrical components using a centre lathe. The material is held firmly in a rotating chuck whilst a cutting tool is brought towards it create the required shape. A variety of processes can be carried out on the lathe for example turning cylinders, creating texture (knurling), accurate drilling and threading.

Drop Forging

Drop forging involves stamping hot malleable metal between two halves of a mould called a die and forming the required shape. The main advantage in using this process is the refining of the grain flow of the material. This makes the metal more dense and thus increases its strength because the grain flow follows the shape of the component. The hot metal is placed between the two dies and a large force applied using a power hammer. Sometimes the work has to go through several dies in order to reach the required shape. Items produced by drop forging include crankshafts and gear blanks.

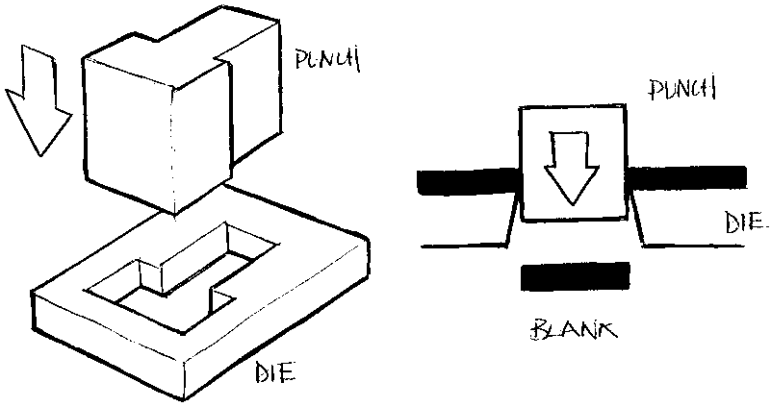


Piercing and Blanking

This is a useful process when a great number of identical items are required. Piercing and blanking refers to punching holes in and stamping shapes out of sheet metal. The processes are the same, the name refers to the pieces produced which are kept. If the *punched* material is kept the process is called *piercing* and if the *stamped* piece is kept the process is called *blanking*.

The process works by passing a strip of metal between a hardened punch and matching die. The punch is forced through the strip and shears on the die. The shape is formed immediately in one press. This process is automated by passing the metal strip through by the exact amount on every stroke.

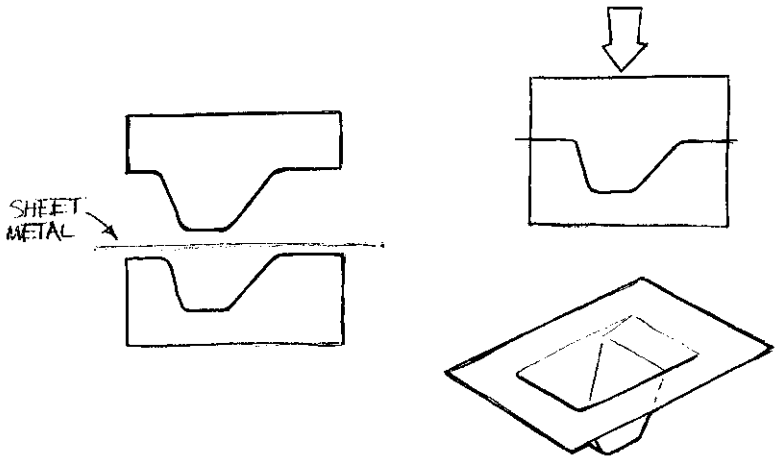
Bicycle chains and jewelry chain links are examples of products made in this way.



Pressing

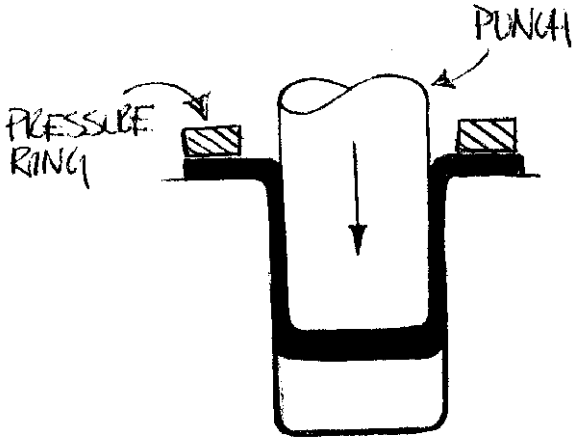
The pressing process uses thin sheet metal to produce strong shell structures which are used in everyday life. Examples of such items are kettles, baking tins, tubular furniture, car bodies and aircraft frames.

The dies for this process are expensive to produce and are used in presses which exert forces of many hundreds of tonnes upon them. The die is made of two parts that allow for the thickness of the metal. Components start out as flat sheets which are then blanked out to the required shape. The large force is then used to press the blank into the required form. In industry press tools can be used to produce complex forms by forming, piercing and drawing the material into shape.



Drawing

The process of drawing is the main process in the production of three dimensional curved pressings e.g. drinks cans. The sheet material (blank) is held in place by a pressure ring which has a highly finished surface plus lubrication to minimise friction. A punch is then forced into the material drawing it down to form the required shape. The depth which can be drawn in one punch depends on the type of material, its tensile strength and the tool design.



Manufacturing Systems

So far we have looked at processes used in industry which help to meet the demands of todays consumer. The following manufacturing systems look at how the modern manufacturing industry is coordinated and how it makes use of new technology in order to be competitive in todays economy.

CAD (Computer Aided Design)

This is a system that uses a powerful computer graphics workstation to enable product designers and engineers to draw design specifications on a display screen. Working with a variety of peripheral devices they can specify a products dimensions, lines, indentations and other features with precision. Alterations can be made to a design quickly and easily by removing or adding details to the drawing on screen. All work can be stored, retrieved, displayed and printed when required.

CAM (Computer Aided Manufacture)

CAD designs are frequently transmitted to CAM systems, which rely on IT (Information Technology) to automate and manage the manufacturing process. Using the CAD data, CAM software controls tools and machines on the factory floor to manufacture the product which was designed on the CAD system. CAM improves the efficiency of the whole manufacturing process by automatically setting the machines for the next job.

CIM (Computer Integrated Manufacturing)

This is a manufacturing system that uses computers to link automated processes in a factory to reduce design time, increase machine utilization, shorten the manufacturing cycle, cut inventories and increase product quality.

CNC (Computer Numerical Control)

Numerical control means control by numbers. Numerical controlled machines are lathes, milling machines, drilling machines and punch presses. All of these machines have their movements and functions controlled by a programmed set of numbers. These numbers are interpreted by the machine tool and a related function is carried out. A CNC machine is controlled by a computer and the moving machine parts are driven by stepper motors. Once the computer has been programmed to make the machine tool perform a set of functions, the program can be run over and over again to produce many identical components.

Advantages of CNC	*Disadvantages of CNC*
Consistent accuracy	Initial machine cost
Increased productivity	Maintenance and servicing costs
Less operator involvement	Installation costs
Complex shapes easy to machine	Operator training
Tooling costs reduced	
Component rejection reduced	
Uniformity of product	
Can operate unattended	