Injection Moulding

This process is normally associated with thermoplastics and used to create complex 3D shapes.

**Step by step**
- Granules of plastic powder or granules are poured or fed into a hopper.
- A motor turns a thread which pushes the granules along the heater section which melts then into a liquid. The liquid is forced into a mould where it cools into the shape.
- The mould then opens and the shape is removed.

**Advantages**
- Very complex 3D shapes can be produced.
- High volumes can be produced with consistent quality.
- Very fast compared to other moulding processes.
- Little labour costs.
- Little waste.
- Little to no finishing of the shapes produced.

**Materials used in this process**
- Polystyrene
- Polythene
- Nylon
- ABS (below)
- Polypropylene (below)

**Disadvantages**
- High initial set-up costs.
- Moulds (pictured) are expensive.

**Example Product**

The Panton Chair is an S-shaped chair first designed by the Danish designer Verner Panton in the 1960s. It is considered the world's first moulded plastic chair and to be a masterpiece of Danish design.

Today's Panton Chairs are manufactured by injection moulding out of polypropylene, which is fully recyclable. Injection moulding technology makes it possible to offer this design classic as an inexpensive version, thereby making it available to a wider market.
Blow Moulding

This process is used in the manufacture of bottles and other containers. Objects produced are usually hollow.

**Step by step**

- The plastic is fed in granular form into a ‘hopper’ that stores it.
- Heated plastic granules are injection moulded into a pre-form shape which is positioned into a mould.
- Air is forced into the mould which forces the plastic to the sides, giving the shape of the bottle.
- The mould is then cooled and is removed.

**Diagram**

1. An injection-moulded pre-form is placed in the mould.
2. Compressed air is injected, blowing the pre-form inside the mould cavity to form the final shape.
3. The mould opens and the part is released.

**Advantages**

- Once set up, blow moulding is a rapid method of producing hollow objects with narrow necks.
- Well suited to low or high production scales.
- Many types of plastic can be used.
- Can be less expensive than injection moulding.

**Example Products**

Although originally made of concrete, today's traffic cones are more commonly brightly coloured thermoplastic. Recycled PVC from bottles can be used to create modern traffic cones. Blow moulding is ideal for traffic cones as they need to be mass produced, easily transported and hollow so they can be filled and weighted down with sand, water or concrete.

**Materials used in this process**

- HDPE
- LDPE
- PP
- PVC
- PET (pictured)

**Disadvantages**

- Limited to hollow parts.
- Moulds can be expensive.
- It is difficult to produce 're-entrant shapes' (shapes that do not allow easy extraction from the mould).
- Difficult to produce triangular shapes.

There are many different kayaks on the market made from different construction methods which all have their advantages and disadvantages. Blow moulding is the most inexpensive form of production, but has the poorest performance properties. It makes for great low prices but the finish and thickness of material may be thin where kayakers really need it thick, such as in the corners on the bottom of the boat. Also you will rarely find a long pointy kayak that has been blow moulded because of problems getting the plastic into the ends.
Vacuum Forming

Sheet plastic is stretched onto or into a single-surface mould, and held against the mould by applying a vacuum.

**Step by step**
- A sheet of plastic is heated to a temperature suitable for forming.
- A mould is then pushed up into the plastic sheet.
- The 'vacuum' is turned on and this pumps out all the air beneath the plastic sheet.
- The sheet has the shape of the former pressed into its surface.

**Advantages**
- Available to schools (pictured), colleges and industry.
- Simple process, easy to use.
- The mould can be made from a range of materials, including inexpensive materials, because the pressures involved are low.
- Suitable for one-off and large scale production.

**Disadvantages**
- Additional processing required is required to trim excess material which produces a lot of waste.
- Moulds must have no vertical sides—draft angles are needed (pictured).
- You can only have undercuts with special moulds.

**Materials used in this process**
- Most Thermoplastic sheet plastic.
  - ABS
  - Polystyrene
  - Acrylic (pictured)
  - Polycarbonate

**Example Products**
Australian designer Marc Newson has designed a carrying case to hold a single bottle for champagne for the brand Dom Pérignon. It is called 'The Black Box'. The packaging is vacuum formed from polycarbonate which is durable and is able to act as a good insulator. It is able to protect its precious contents from shock and temperature variations, thus preserving it and making a design statement.

Moulds used to create garden ponds are often vacuum formed. They can be produced quickly and on a large scale (sometimes one every five minutes) making them affordable and available across garden centres nationwide.
Plastic Extrusion

Plastic extrusion is the process where plastic is formed into a shape with a continuous profile.

**Step by step**
- Granules of plastic powder or granules are poured or fed into a hopper.
- A motor turns a thread which pushes the granules along a heater section.
- The heater softens the plastic which is then forced through a die.
- As the plastic leaves the die it is cooled.
- The extruded product is then cut to the required length.

**Advantages and disadvantages**
- The best way to make long products with the same profile.
- Only requires simple dies (pictured below and right).
- Parts need to be cut to shape, assembled or drilled.
- Not suitable for one-off productions (unless your one-off is 50 meters long!).

**Materials used in this process**
Extrusion can be used with a range of materials. As well as plastics aluminium, wood-plastic composites and ceramics are commonly extruded.

**Example Products**
Plastic drinking straws are made from extruded polypropylene. During the extrusion process the heated polypropylene resin exits the die in a long string in the shape of a straw. This elongated tube is directed through a cooling stage—usually a water bath. Some operations run the plastic over a chilled metal rod, called a mandrel, which freezes the internal dimension of the straw to that of the rod. It is continuously moved along by a puller which helps maintain the shape of the straw as it is moved through the manufacturing process. Ultimately, the long tubes are cut to the proper length by a knife assembly.

Polypropylene has many properties which make it suitable for use in straw manufacturing. It is light-weight, has fair abrasion resistance, good dimensional stability, and good surface hardness. It typically does not experience problems with stress cracking and it offers excellent chemical resistance at higher temperatures. Most importantly for extrusion, it has good thermoplastic properties.

Another key attribute of this plastic is that it is safe for contact with food and beverage. Polypropylene is approved for indirect contact with food.

The major waste product from straw manufacturing is the plastic resin, which is contaminated, overheated, or otherwise ruined must be discarded. However, straws, which fail for other reasons, can be reworked. This process of reusing plastic is known as regrinding and involves pulverizing the straws and re-melting them. This can be done without loss of quality because of the thermoplastic nature of polypropylene.
Laser Cutting

A highly accurate form of cutting and decorating materials using a fine beam of light controlled by a CNC machine.

Advantages

- Can engrave and cut materials by adjusting the power output.
- Highly complex shapes can be produced.
- Suited to batch production.
- Gives a clean edged cut on acrylic and metals.
- A much broader range of materials can be cut compared to plasma cutting.
- Low maintenance/no tool wear.

Disadvantages

- Can leave burn marks on wood and paper materials.
- Highly polished or reflective surfaces decrease the effectiveness of the laser.
- Very energy intensive.
- Slow when working with thicker materials.
- Material wastage is often high.
- Not suitable for large scale production.
- There is an optimum thickness from which materials can be cut.

Materials used in this process

- Paper
- Copper
- Card
- Stainless steel
- MDF
- Aluminium
- Plywood
- Gold
- Acrylic
- Silver

Example Products

Designer Barend Massow makes interesting laser cut lighting pieces inspired by traditional lighting forms. These examples (above) were cut from plywood and acrylic.

Because of the high level of accuracy and finishing quality that can be achieved laser cutting is often used in the production of intricate batch produced products such as jewellery. Pictured is some acrylic earrings.

The great level of accuracy that can be achieved from laser cutting plywood allows for easy, no glue, assembling toy kits that can be easily flat packed.

A laser cut acrylic shop sign.
Sand Casting

A low cost method of casting metal in sand moulds. Used for one-off or low volume production.

Step by step

- A pattern is made.
- Each part of the pattern is placed on a base board. A mould box half is placed over it.
- Sand is packed around the pattern forcing it into contact with the pattern.
- The pattern is removed from the mould half.
- The mould halves are fitted together with locating pins ensuring correct alignment.
- Molten metal is poured into the running gate.
- Once the metal has solidified the mould is broken open.

Advantages

- Low cost process.
- Easy to operate.
- Advanced sand casting can produce very detailed and intricate parts.
- Flexible levels of production.

Disadvantages

- Can be labour intensive.
- Unit costs can be high when used for one-off production.
- Parts may require a lot of finishing.

Materials used in this process

Metals with a low melting point. These include:

- Copper alloys
- Lead
- Zinc
- Aluminium
- Tin
- Certain steels
Wood Laminating

Multiple sheets of wood veneer are formed using moulds and bonded together using strong adhesives, to produce rigid, light weight structures.

Image

Step by step

- Adhesive is applied to the face of each veneer.
- Each veneer is stacked on top of the other (lay-up).
- The veneers are clamped into position in a die (pictured below and above).
- The adhesive is dried and the shape is formed.

Diagram

Advantages

- Suitable for one-off, batch and mass production.
- Can accommodate a range of thicknesses.
- Creates strong and lightweight products and components.
- Can be combined with other materials to enhance properties such as in snowboards (pictured).

Example Products

The Eames Lounge Chair and ottoman, was released in 1956 after years of development by designers Charles and Ray Eames. It was designed for a high-end market. It is made of laminated plywood and leather. Examples of this design are part of the permanent collection of New York’s Museum of Modern Art. The chair has become iconic with Modern style design. The chair is composed of three curved plywood shells. In modern production the shells are made up of seven thin layers of wood veneer glued together and shaped under heat and pressure. The design is considered to be one of the first to make use of moulded plywood, which was devised during WWII for leg and arm splints. The original (vintage) chairs made use of luxurious materials such as rosewood faced plywood, cast aluminium and leather to create organic shaped seating shells.

Disadvantages

- Involves many steps.
- Restricted to bends in a single direction.

Materials used in this process

Wood veneers.
- Birch is used in majority of mass produced furniture.

Supplies of birch veneers (above)

This elegant stackable stool designed by Shin Azumi is formed from a single sheet of plywood. The seat and the body of the stool merge seamlessly. The wide spread of the base helps to disperse pressure.
Brazing

A way of forming permanent joints in metal by melting a brazing rod at 880°C between two parts.

**Step by step**

- The metal to be joined must first be cleaned so that grease and dirt is removed.
- Flux is brushed along the joint to prevent oxidation taking place on the metal surfaces.
- Pressurised gas and air is fed through a nozzle and ignited.
- The joint is heated with the flame until eventually it becomes so hot that it becomes red in colour.
- A brazing rod (copper-zinc alloy) is then pushed gently against the joint and if the temperature is right the end of the rod will melt and begin to run along the joint. The rod is fed into the joint until a brazed joint is complete.

**Advantages**

- **LOW COSTS.**
- Does not affect the properties of the materials being grazed.
- Suitable for one-off through to mass production.
- Depending on size of joint and technique this process takes little time.
- The bond is very strong—close to the strength of the parent material.
- Can produce a clean joint without the need for secondary finishing.
- Complex and intricate joints can be achieved.
- Very few rejects as faulty joints can be dismantled and re-joined.

**Disadvantages**

- Requires a high degree of cleanliness.
- The joint colour is often different from that of the base metal, creating an aesthetic disadvantage. Although this can be changed or the materials painted.
- Not as strong as a welded joint.

**Materials used in this process**

- Copper
- Steel (particularly mild steel).

**Example Products**

The stainless steel Alessi Bombe Milk Jug was designed by Carlo Alessi in 1945 and is still in production today. Brazing is used to join the spout and handle. Brazing is used to maintain the integrity of the original design. An overlap has been created between the spout and body to maximize the surface area being joined. The wok is done in a jig and the whole process lasts about 30 seconds. Very little finishing is required, the brazed part is removed from the jig and lightly polished.

Brazed bicycle parts.
TIG (Tungsten Inert Gas) Welding

A precise and high quality form of electric arc welding that uses a non-consumable tungsten electrode.

Step by step
- TIG generates heat via an arc of electricity jumping from a (tungsten metal) electrode to the metal surfaces you intend to weld.
- The heat is sufficient to melt the joint edges.
- The electrode is coated in flux which when melted, prevents the joint becoming oxidized.

Advantages
- Using Tungsten to provide its electrical current, TIG welding decreases the amount of sparks, smoke and fumes produced.
- TIG welding has less contamination in its weld, providing more precise and higher quality welds.
- No tooling costs.

Disadvantages
- TIG welding requires more setup time than MIG welding and is not as user-friendly.
- TIG welds tend to be more expensive and take longer than MIG welding, especially in thicker metals.
- TIG welding is more complex and requires more skill than the MIG welding process.

Materials used in this process
- Carbon Steel
- Stainless Steel
- Aluminum.

It is the main process for joining:
- Titanium.