

# UNIT V

## Manufacturing of Plastic Components

### Plastic

- **Plastic** is the general common term for a wide range of synthetic or semi synthetic organic amorphous solid materials suitable for the manufacture of industrial products.
- Plastics are typically polymers of high molecular weight, and may contain other substances to improve performance and/or reduce costs.

### Types of Plastics

- Plastics can be divided into two major categories:
  1. **Thermoset or thermosetting plastics.** Once cooled and hardened, these plastics retain their shapes and cannot return to their original form. They are hard and durable. Thermosets can be used for auto parts, aircraft parts and tires.

Examples include polyurethanes, polyesters, epoxy resins and phenolic resins.

2. **Thermoplastics.** Less rigid than thermosets, thermoplastics can soften upon heating and return to their original form. They are easily molded and extruded into films, fibers and packaging.

Examples include polyethylene (PE), polypropylene (PP) and polyvinyl chloride (PVC).

### Thermoset or Thermosetting Plastics

1. **Polyurethane Plastics :-** Polyurethane plastics belong to the group that can be thermosetting. Polyurethane is the only plastic which can be made in both rigid and flexible foams. The flexible polyurethane foam is used in mattresses, carpets, furniture etc. The rigid polyurethane foam is used in chair shells, mirror frames and many more. Due to the property of high elasticity, some polyurethane plastics are used in decorative and protective coatings. The high elasticity makes these polyurethane plastics resistant to a chemical attack.

2. **Epoxy**

Epoxyes are used in numerous ways. In combination with glass fibers, it is capable of producing composites that are of high strength and that are heat resistant. This composite is typically used for filament wound rocket motor casings in missiles, in aircraft components, and in tanks, pipes, tooling jigs,

pressure vessels, and fixtures. Epoxies are also found in gymnasium floors, industrial equipment, sealants, and protective coatings in appliances.

### 3. Phenolic

Phenolic plastics are thermosetting resins used in potting compounds, casting resins, and laminating resins. They can also be used for electrical purposes and are a popular binder for holding together plies of wood for plywood.

## Thermoplastics

### 1.Vinyl Plastics :-

Vinyl plastics belong to the thermoplastic group. Vinyl plastics are the sub-polymers of vinyl derivatives.

These are used in laminated safety glasses, flexible tubing, molded products etc.

**2.Polyacrylics Plastics :-** Polyacrylics belong to the group of thermoplastics. Polyacrylics are transparent and decorative. Polyacrylics plastics can be shaped in any form like the windshields for airplane.

### 3.Polyvinyl Chloride

Polyvinyl Chloride, commonly referred to as PVC or vinyl, was first invented in Germany around 1910. It didn't become a useful product in the United States, however, until the late 1920s. It became particularly useful during World War II when it was used as a substitute for rubber, which was in short supply. Polyvinyl Chloride is resistant to abrasion and is both weather and chemical resistant. Today, it is commonly found in upholstery, wall coverings, flooring, siding, pipe, and even apparel. In fact, vinyl is perhaps the best known of all plastics.

**4.Polyethylene Terephthalate (PETE) :-** PETE is one the most recycled plastic. It finds usage in various bottles like that of soda and cooking oil, etc.

**5.High Density Polyethylene (HDPE) :-** HDPE is generally used in detergent bottles and in milk jugs.

**6.Polyvinyl Chloride (PVC) :-** PVC is commonly used in plastic pipes, furniture, water bottles, liquid detergent jars etc.

**7.Low Density Polyethylene (LDPE) :-** LDPE finds its usage in dry cleaning bags, food storage containers etc.

**8.Polypropylene (PP) :-** PP is commonly used in bottle caps and drinking straws.

**9.Polystyrene (PS) :-** PS is used in cups, plastic tableware etc.

Symbol	Type of Plastic	Properties	Common Uses	Recycled In
	<b>PET</b>  Polyethylene Terephthalate	Clear, tough solvent resistant, barrier to gas and moisture, softens at around 80°C	Soft drink and water bottles, salad domes, biscuit trays, salad dressing and peanut butter containers	Pillow and sleeping bag filling, clothing, soft drink bottles, carpet
	<b>PE-HD</b>  High Density Polyethylene  (HDPE)	Hard to semi-flexible, resistant to chemicals and moisture, waxy surface, opaque, softens at around 75°C, easily colored, processed and formed	Crinkly shopping bags, freezer bags, milk bottles, ice cream containers, juice bottles, shampoo, chemical and detergent bottles, buckets, rigid agricultural pipe, milk crates	Recycling bins, compost bins, buckets, detergent containers, posts, fencing, pipes
	<b>PVC</b>  Unplasticised Polyvinyl  Chloride PVC-U	Strong, tough, can be clear, can be solvent welded, softens at around 80°C	Cosmetic containers, electrical conduit, plumbing pipes and fittings, blister packs, wall cladding, roof sheeting, bottles	Flooring, film and sheets, cables, speed bumps, packaging, binders, mud flaps and mats
	Plasticised Polyvinyl Chloride PCV-P	Flexible, clear, elastic, can be solvent welded	garden hose, shoe soles, cable sheathing, blood bags and tubing, watch straps	

## Characteristics of Plastics

- **Mechanical properties**

Mechanical properties refer to displacement or breakage of plastic due to some mechanical change such as applying some load.

Mechanical properties are dependent on the temperature, force (load), and the duration of time the load is applied. It may also be affected by ultra-violet radiation when used outside.

- **Thermal properties**

Thermal properties include heat resistance or combustibility.

Thermoplastic has a larger coefficient of thermal expansion or combustibility and a smaller thermal conductivity or specific heat than other material such as metals.

- **Chemical properties**

Chemical resistance, environmental stress crack resistance, or resistance to environmental change are referred as chemical properties.

When a plastic contacts chemicals, there is some kind of change. After having a plastic in contacted with chemicals under no stress for about a week, changes in appearance, weight and size of the plastic are examined. Such changes are referred to as chemical properties.

- **Electric properties**

Electric properties are also referred to as electromagnetic properties. Electric properties include insulation, conductivity and electro-static charges.

Due to their good insulation property, plastics are often used in electric fields. However, plastics do have a defect; they are easily electrified.

- **Physical properties**

Specific gravity, index of refraction and moisture absorption are called physical properties. The specific gravity of the plastic is small, and it varies depending on the character of high polymer , or thermal and mechanical treatment of the plastic.

## **Materials for Processing Plastics**

Most Plastic resins have to be combined, compounded, or otherwise chemically treated with processing materials before they are ready for processing.

One of the following additions are usually employed;

1. Plasticizers
2. Fillers
3. Catalyst
4. Initiators
5. Dyes and Pigments

1. **Plasticizers**

- i) Organic Solvents, resins, and even water are used as plasticizers.
- ii) These substances act as internal lubricants improving flow of and giving toughness and flexibility to the material
- iii) Plasticizers are also used to prevent crystallization by keeping the chains separated from one another.

## **2. Fillers**

i) Typical fillers which include wood flour, asbestos fibre, glass fibre, cloth fibre, mica, slate powders, may be added in high proportion to many plastics essentially to improve strength, dimensional stability, and heat resistance.

## **3. Catalyst**

These are usually added to promote faster and more complete polymerization.

As such they are also called accelerators and hardeners.

## **4. Initiators**

It is used to initiate the reaction, i.e., to allow polymerization to begin

They stabilize the ends or reaction sites of the molecular chains.

H<sub>2</sub>O<sub>2</sub> is a common initiator.

## **5. Dyes and Pigments**

These are added in many cases, to color the material to different shades

# **Plastic Processes**

1. Moulding Process
2. Calendering Process
3. Thermoforming
4. Casting
5. Fabrication Process

## **1. Moulding Processes**

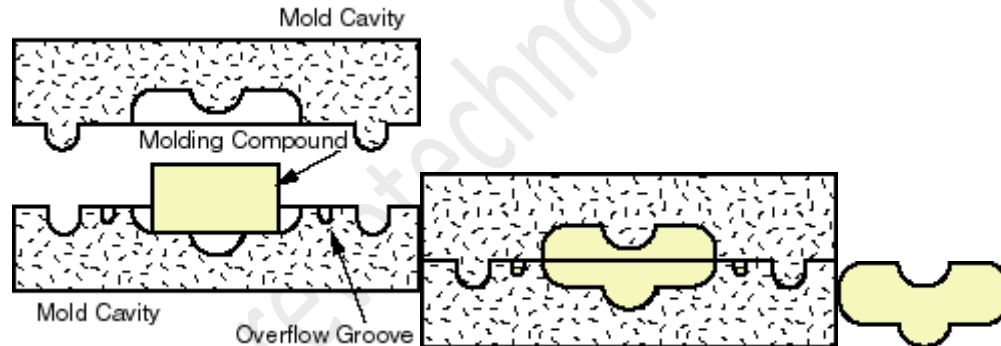
- i. Compression Moulding
- ii. Transfer Moulding
- iii. Injection Moulding
- iv. Jet Moulding
- Extrusion

# Compression molding

- *Compression molding* is a method of molding in which the molding material, generally preheated, is first placed in an open, heated mold cavity. The mold is closed with a top force or plug member, pressure is applied to force the material into contact with all mold areas, while heat and pressure are maintained until the molding material has cured.

## Common plastics used in compression molding processes include

- Polyester
- Polyimide (PI)
- Polyamide-imide (PAI)
- Polyphenylene Sulfide (PPS)
- Polyetheretherketone (PEEK)
- Fiber reinforced plastics



## Principle of working

- The compression molding starts, with an allotted amount of plastic or gelatin placed over or inserted into a mold.
- Afterward the material is heated to a pliable state in and by the mold.
- Shortly there after the hydraulic press compresses the pliable plastic against the mold, resulting in a perfectly molded piece, retaining the shape of the inside surface of the mold.

- After the hydraulic press releases, an ejector pin in the bottom of the mold quickly ejects the finish piece out of the mold and then the process is finished.
- Also depending on the type of plunger used in the press there will or won't be excess material on the mold.

### **Factors affecting Compression Moulding**

- Amount of material
- Heating time and technique
- Force applied to the mold
- Cooling time and technique

### **Advantages**

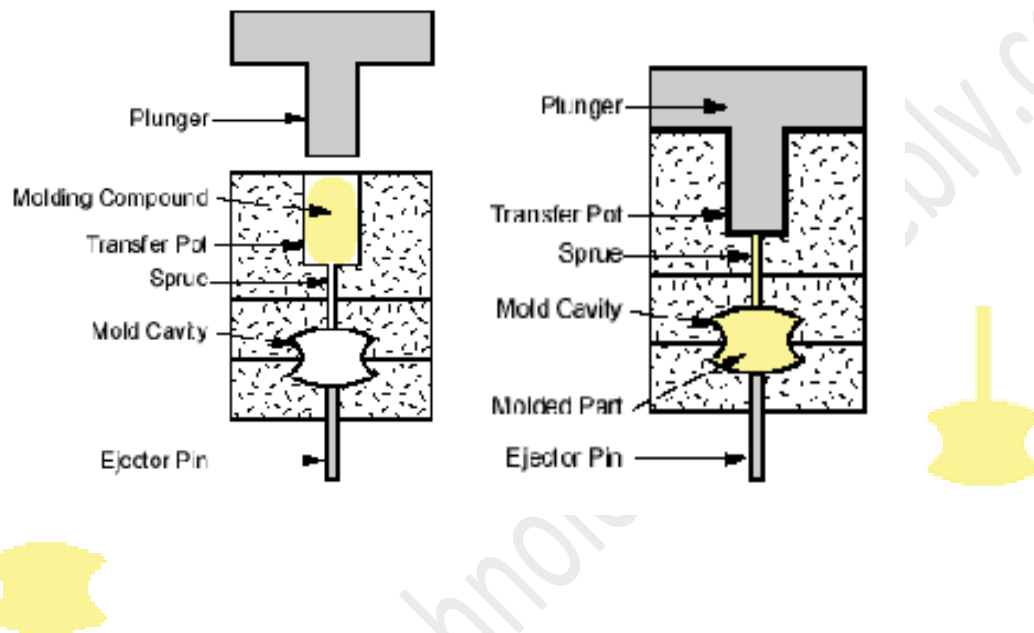
- Low initial setup costs
- Fast setup time
- Capable of large size parts beyond the capacity of extrusion techniques
- Allows intricate parts
- Good surface finish (in general)
- Wastes relatively little material
- Can apply to composite thermoplastics with unidirectional tapes, woven fabrics, randomly orientated fiber mat or chopped strand
- Compression molding produces fewer knit lines and less fiber-length degradation than injection molding.

### **Disadvantages**

- Production speed is not up to injection molding standards
- Limited largely to flat or moderately curved parts with no undercuts
- Less-than-ideal product consistency

## **Transfer molding**

- Transfer molding is similar to compression molding in that a carefully calculated, pre-measured amount of uncured molding compound is used for the molding process.
- The difference is, instead of loading the polymer into an open mold, the plastic material is pre-heated and loaded into a holding chambers called the pot.
- The material is then forced/transfered into the pre-heated mold cavity by a hydraulic plunger through a channel called sprue. The mold remains closed until the material inside is cured.



### Process in Transfer molding

1. The pre-heated, uncured molding compound is placed in the transfer pot.
2. A hydraulically powered plunger pushes the molding compound through the sprue(s) into the pre-heated mold cavity. The mold remains closed until the material inside is cured (thermosets) or cooled (thermoplastics).
3. The mold is split to free the product, with the help of the ejector pins.
4. The flash and sprue material is trimmed off.

### Plastic used in this Process

- Epoxy
- Polyester (Unsaturated)



- Phenol-formaldehyde Plastic (PF, Phenolic)
- Silicone rubber (SI)

### Advantages

- Product consistency better than compression molding, allowing tighter tolerance and more intricate parts
- Production speed higher than compression molding
- Fast setup time and lower setup costs than injection molding
- Lower maintenance costs than injection molding
- Ideal for plastic parts with metal inserts

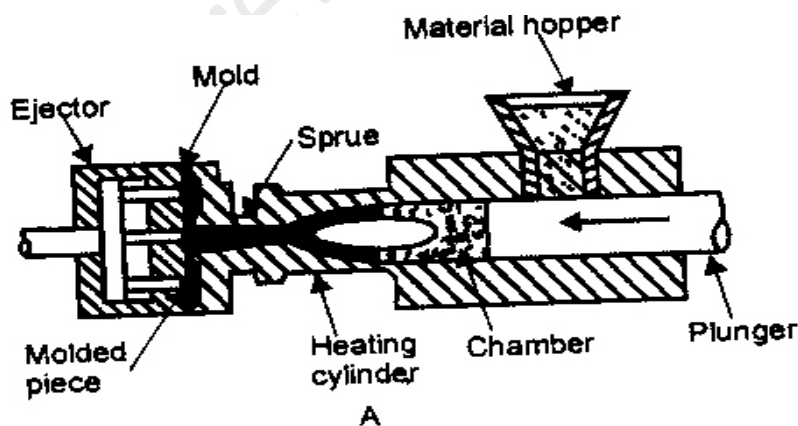
### Disadvantages

- Wastes more material than compression molding (scraps of thermosets are not re-useable).
- Production speed lower than injection molding

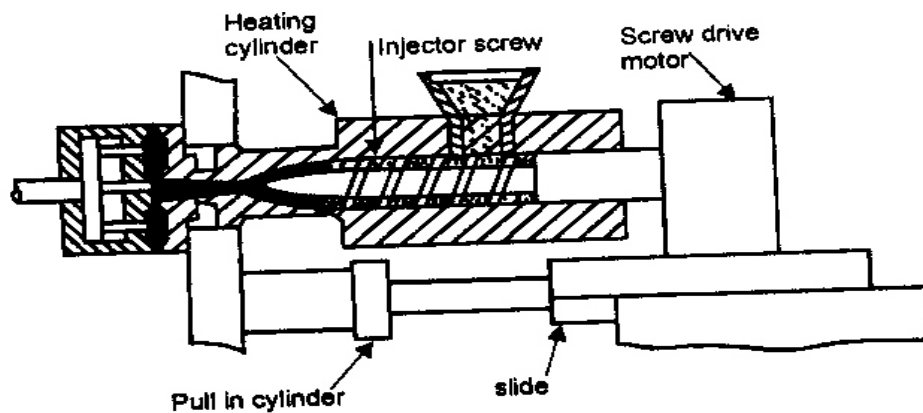
## Injection molding

- **Injection molding** is a manufacturing process for producing parts from both thermoplastic and thermosetting plastic materials.
- Material is fed into a heated barrel, mixed, and forced into a mold cavity where it cools and hardens to the configuration of the mold cavity.

### Conventional Single Stage Plunger Type



### Single Stage Reciprocating Screw Type



### Two stage plunger or Screw plasticiser type

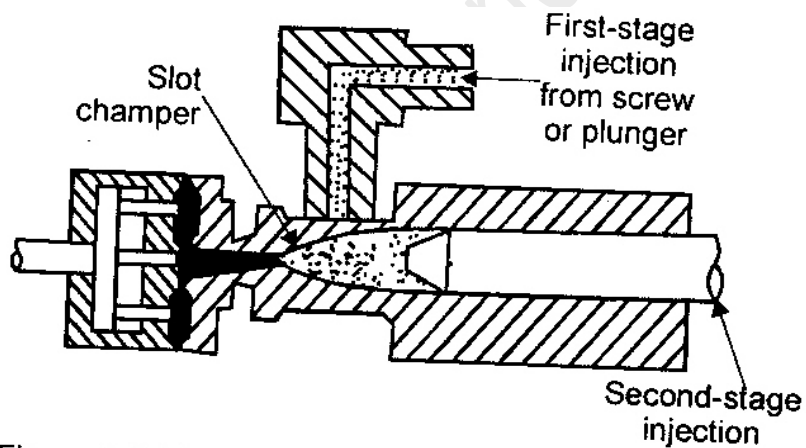


Figure 5.4 (c) Two stage plunger-or-screw-plasticiser type

### Process of Injection Moulding

- The process start with feeding plastic pellets in the hopper above the heating cylinder of the machine.

- The resin falls into and is pushed along the heated tube by reciprocating screw until a sufficient volume of melted plastic available
- This may take from 10 Sec to 6 min.
- The entire screw is then plunged forward to force the plastic into the mould.
- Each shot may produce one or several parts, depending on the die used.
- The ram is held under pressure for a few seconds so that the moulded part can solidify.
- It then retracts slightly, and the mould open
- Knockout pins eject the moulded piece.

### **Applications**

- Milk cartons,
- Packaging
- Bottle caps
- Automotive dashboards
- Pocket combs
- And most other plastic products available today.

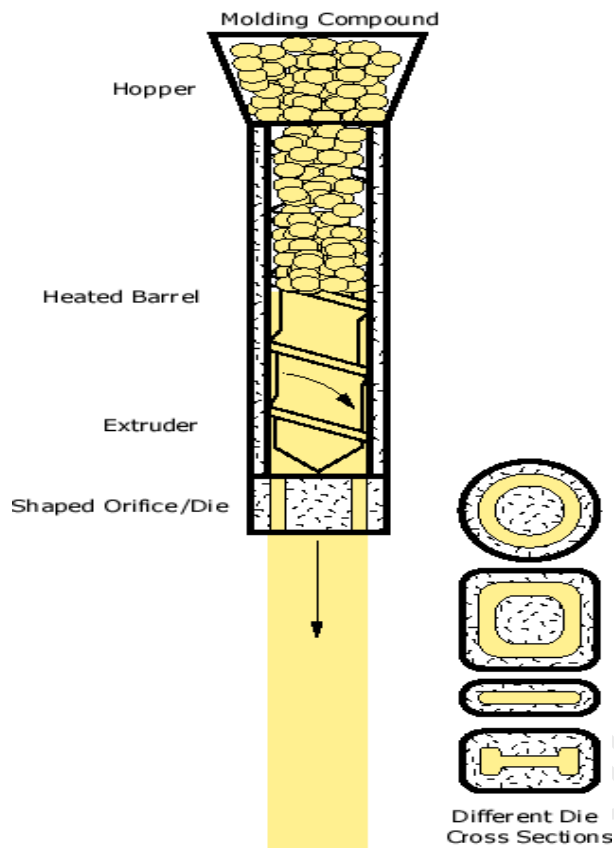
### **Jet Moulding**

- A modified version of the Injection moulding is known as Jet Moulding Process.
- In this process the Plastic is preheated to about 93°C in the cylinder surrounding to nozzle.
- It is further heated as the plunger forces the resin through the nozzle.
- After the mould has been filled, the nozzle is cooled by running water to prevent polymerization of the remaining material.

### **Extrusion Moulding**

- Extrusion is one of the most widely used manufacturing processes across many industries.
- Essentially, it is not much different from squeezing tooth paste out of the tube.
- Anything that is long with a consistent cross section is probably made by extrusion.

- Common examples are spaghetti, candy canes, chewing gums, drinking straws, plumbing pipes, door insulation seals, optical fibers, and steel or aluminum I-beams.



### Process

- The plastic extrusion molding process usually begins with a thermoplastic in the form of pellets or granules.
- They are usually stored in a hopper (a funnel-shaped receptacle) before they are delivered to a heated barrel.
- The molten plastic is then forced through a shaped orifice, usually a custom steel die with shape of the cross section of the intended part, forming a tube-like or rod-like continuous work piece.
- Cooling of the work piece should be as even as possible.

### Plastics used in this process

- Acrylonitrile Butadiene Styrene (ABS)
- Acrylic
- Polycarbonate (PC)

- Polyethylene (PE)
- Polypropylene (PP)
- Polyester
- Polystyrene (PS)
- Polyvinylchloride (PVC)

#### **Advantages**

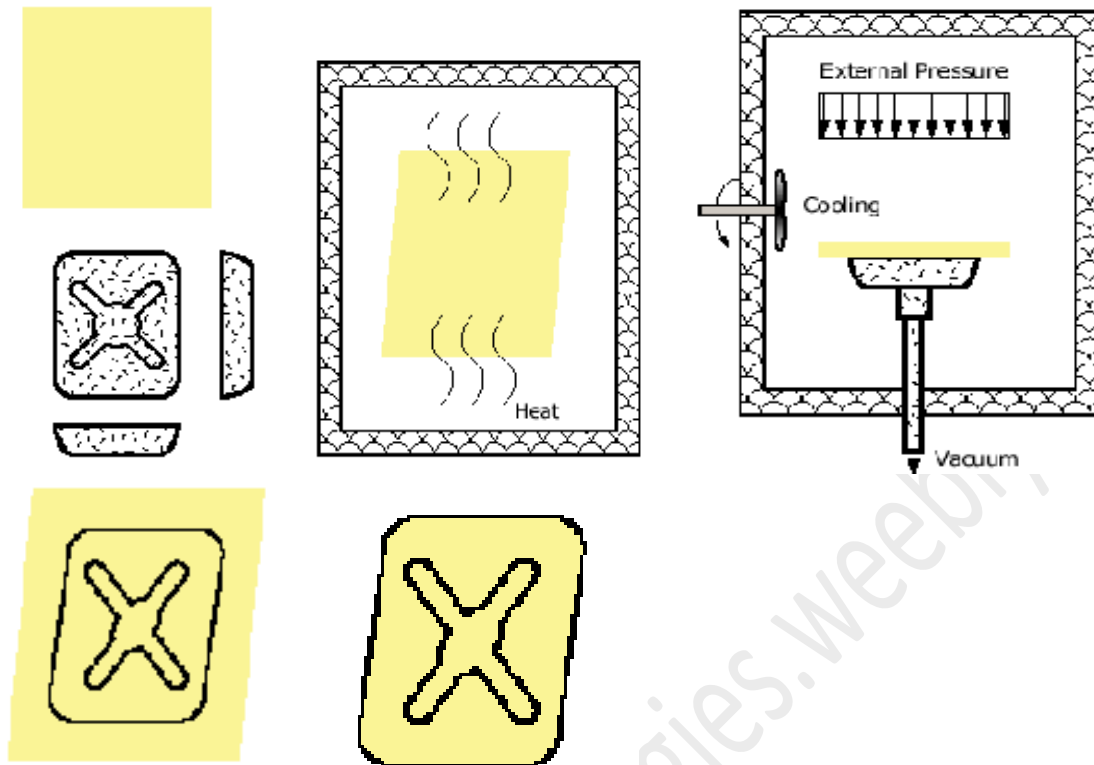
- Low initial setup costs
- Fast setup time
- Low production costs

#### **Disadvantages**

- Moderate production speed
- Average precision
- Limited to parts with a uniform cross section

## **Thermoforming Process**

- A plastic thermoforming process usually begins with a sheet of thermoplastic material formed by the extrusion process using a slotted die.
- Thin-gage materials (less than 1/16 inch thick) usually come in rolls; and heavy-gage materials (up to 1/2 inch thick) normally come in sheets.
- The sheet of plastic material is first heated to become a flexible membrane.
- This soft, rubber-like membrane is placed on the mold and stretched to cover the entire surface.
- Vacuum, external air pressure, and mechanical forces are used to rid the air bubbles and improve the surface quality.
- The plastic part remains in the mold until it solidifies. Excess material is trimmed after the part is removed from the mold.



### Process in Thermoforming

1. The plastic sheets used in thermoforming is usually made by extrusion. The one-sided mold is usually made by aluminum.
2. This sheet of plastic material is first heated to become a flexible membrane. It is soft but still not liquid or gooey.
3. The soft, rubber-like membrane is placed on the mold and stretched to fit. Vacuum, external air pressure, and mechanical forces are used to rid the air bubbles.
4. The plastic part is removed from the mold after it cools and hardens.
5. Trimming, drilling, and other finishing processes may be needed to obtain the final product

**Aluminum** is the most common thermoforming mold material due to its very high coefficient of thermal conductivity that allows speedy and consistent cooling cycle.

### Plastics used in this process

- Acrylonitrile Butadiene Styrene (ABS)
- Acrylic

- Polycarbonate (PC)
- Polyethylene (PE)
- Polypropylene (PP)
- Polystyrene (PS)
- Polyvinylchloride (PVC)

#### Advantages

- Low initial setup costs
- Fast setup time
- Low production costs
- Less thermal stresses than injection molding and compression molding
- More details and better cosmetics than rotational-molded products

#### Disadvantages

- Geometries limited to thin shells or shallow shapes
- One side of the product can be precisely controlled by the mold dimensions while the other side can not.

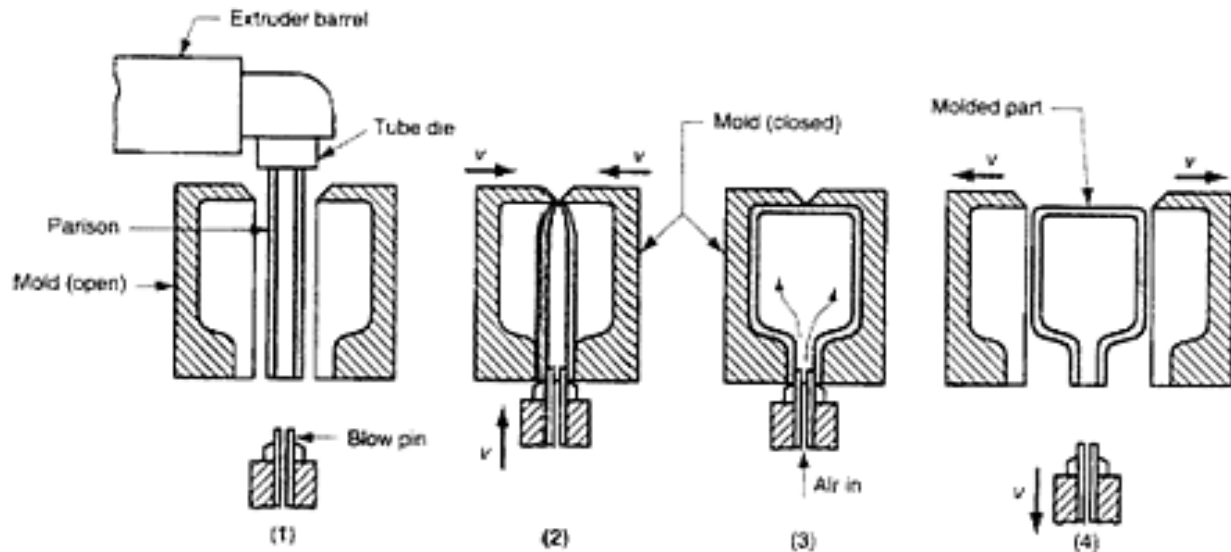
## Blow Moulding

- **Blow molding**, also known as **blow forming**, is a manufacturing process by which hollow plastic parts are formed. It is a process used to produce hollow objects from thermoplastic.

In general, there are three main types of blow molding:

- i. **Extrusion Blow Molding,**
- ii. **Injection Blow Molding, And**
- iii. **Stretch Blow Molding.**

## Extrusion Blow Moulding



- Extrusion Blow Molding is the simplest type of blow molding. A hot tube of plastic material is dropped from an extruder and captured in a water cooled mold. Once the molds are closed, air is injected through the top or the neck of the container; just as if one were blowing up a balloon. When the hot plastic material is blown up and touches the walls of the mold the material "freezes" and the container now maintains its rigid shape.
- Extrusion Blow molding allows for a wide variety of container shapes, sizes and neck openings, as well as the production of handle-ware. Some extrusion machines can produce 300 to 350 bottles per hour. Extrusion blown containers can also have their gram weights adjusted through an extremely wide range, Extrusion blow molds are generally much less expensive than injection blow molds and can be produced in a much shorter period of time.

### Advantages of extrusion blow molding

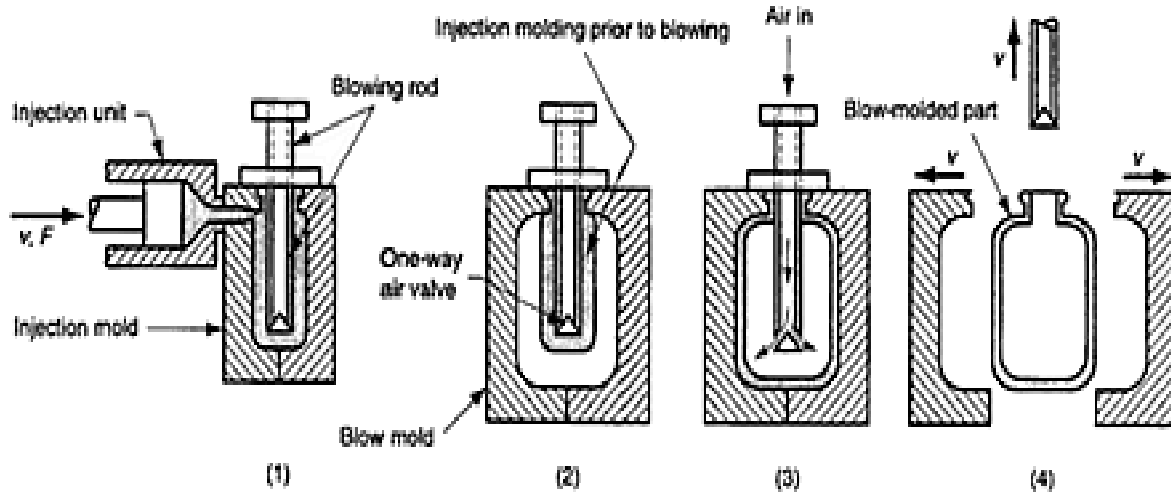
- high rate of production,
- low tooling cost, and a vast majority of machine manufactures. Some disadvantages usually include a high scrap rate, a limited control over wall thickness, and some difficulty of trimming away excess plastic.

### Disadvantages



- include a high scrap rate,
- a limited control over wall thickness,
- and some difficulty of trimming away excess plastic.

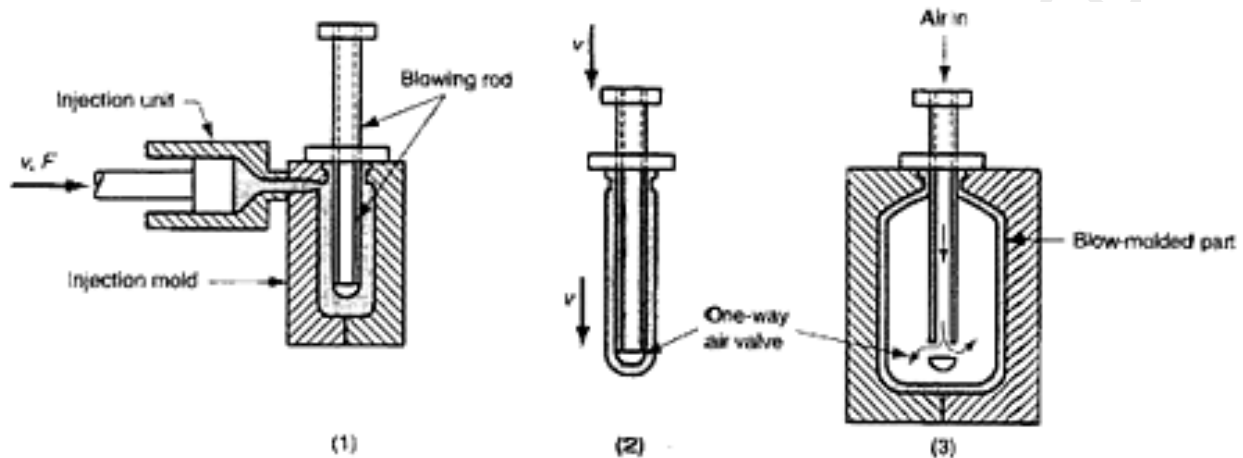
### Injection Blow Molding



- Injection blow molding is part injection molding and part blow molding. Injection blow molding is generally suitable for smaller containers and absolutely no handles ware. Injection blow molding is often used for containers that have close tolerance threaded necks, wide mouth openings; solid handles, and highly styled shapes. Injection blown containers usually have a set gram weight which cannot be changed unless a whole new set of blow stems are built. Generally injection blow molded container's material is distributed evenly throughout, and generally do not need any trimming or reaming. The air is injected into the plastic at a rate between 75 to 150 PSI.
- Injection molding can be broken down into three stages.
- The first stage is where the melted plastic is injected into a split steel mold cavity from the screw extruder.
- The mold produces a preform parison which resembles a test tube with a screw finish on the top.
- The preform is then transferred on a core rod to the second part of the injection blow molding stage. The preform is then placed inside another cold and usually aluminum blow mold cavity.
- Air is then injected through the core rod till the preform takes the shape of the cavity.

- While still on the core rod, the container is then transferred to a desired location for the third stage, where it is ejected from the machine.

### Stretch Blow Moulding



- Stretch blow molding is best known for producing PET bottles commonly used for water, juice and a variety of other products. Stretch blow molding has been used since the early 1970's especially for packaging detergent, and has grown in existence with the primary use for making carbonated beverage bottles.
- One of the major advantages of stretch blow molding is the ability to stretch the preform in both the hoop direction and the axial direction. This biaxial stretching of material increases the tensile strength, barrier properties, drop impact, clarity, and top load in the container. With these increases it is usually possible to reduce the overall weight in a container by 10 to 15 percent less than when producing a container in another way.

### Types of Stretch Blow Moulding

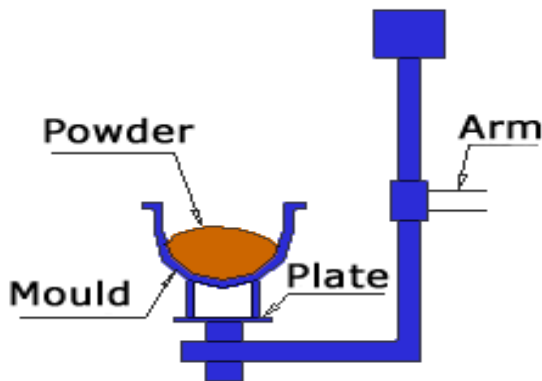
**Stretch blow molding is divided into two different categories single-stage and two-stage.**

- Single-stage uses the extruder to inject parison into a preform mold where the plastic is rapidly cooled to form the preform. The preform is then reheated and placed in the bottle mold. Then softened parison stretches to about twice its original length. Compressed air is then blown into the stretched parison to expand to the bottles mold. Once the bottle is cooled the mold is opened and the finished bottle is emptied from the mold cavity. This technique is most effective

in specialty applications, such as wide mouthed jars, where very high production rates are not a requirement.

- Two-stage stretch blow molding is the same as single-stage, except the preforms are already made. The single-stage process is usually done using one machine, where the two-stage process uses preforms that have already been made and cooled. This allows companies to either make or buy their own preforms. Because of the relatively high cost of molding and RHB equipment, this is the best technique for producing high volume items such as carbonated beverage bottles. In this process, the machinery involved injection molds a preform, which is then transferred within the machine to another station where it is blown and then ejected from the machine. This type of machinery is generally called injection stretch blow molding (ISBM) and usually requires large runs to justify the very large expense for the injection molds to create the preform and then the blow molds to finish the blowing of the container. This process is used for extremely high volume runs of items such as wide mouth peanut butter jars, narrow mouth water bottles, liquor bottles etc.

## Rotation Moulding



### 1. Mould charging

**Rotational molding or moulding** is a versatile process for creating many kinds of mostly hollow items, typically of plastic. The phrase is often shortened to **rotomolding** or **rotomoulding**.

#### 1. Mould charging:

A predetermined charge of cold plastic powder is placed in one half of a cold mould, which is then closed.

2. **Mould rotation and heating:**

The arm with the mould is then inserted into the oven, where the plastic is warmed up to the right melting temperature. The mould is rotated biaxially in this heated oven. Thus, the plastic powder inside the mould starts to melt and coat the inside surface of the mould. The rotation of the mould continues until all plastic powder has melted and is evenly divided inside the mould.

3. **Mould cooling:**

As the biaxial rotation continues, the arm with the mould is transferred to a cooled environment. There, air, water or a combination of both is used to cool the mould and the molten plastic. The cooling process continues until the plastic has solidified and the plastic product maintains its form.

4. **De-moulding of the final product:**

After the cooling, the rotational arm is transferred to the load and unload station. The mould is opened and the product is de-moulded. When the product is de-moulded, the mould can be charged again with powder and the process can start all over again.

### **Advantages**

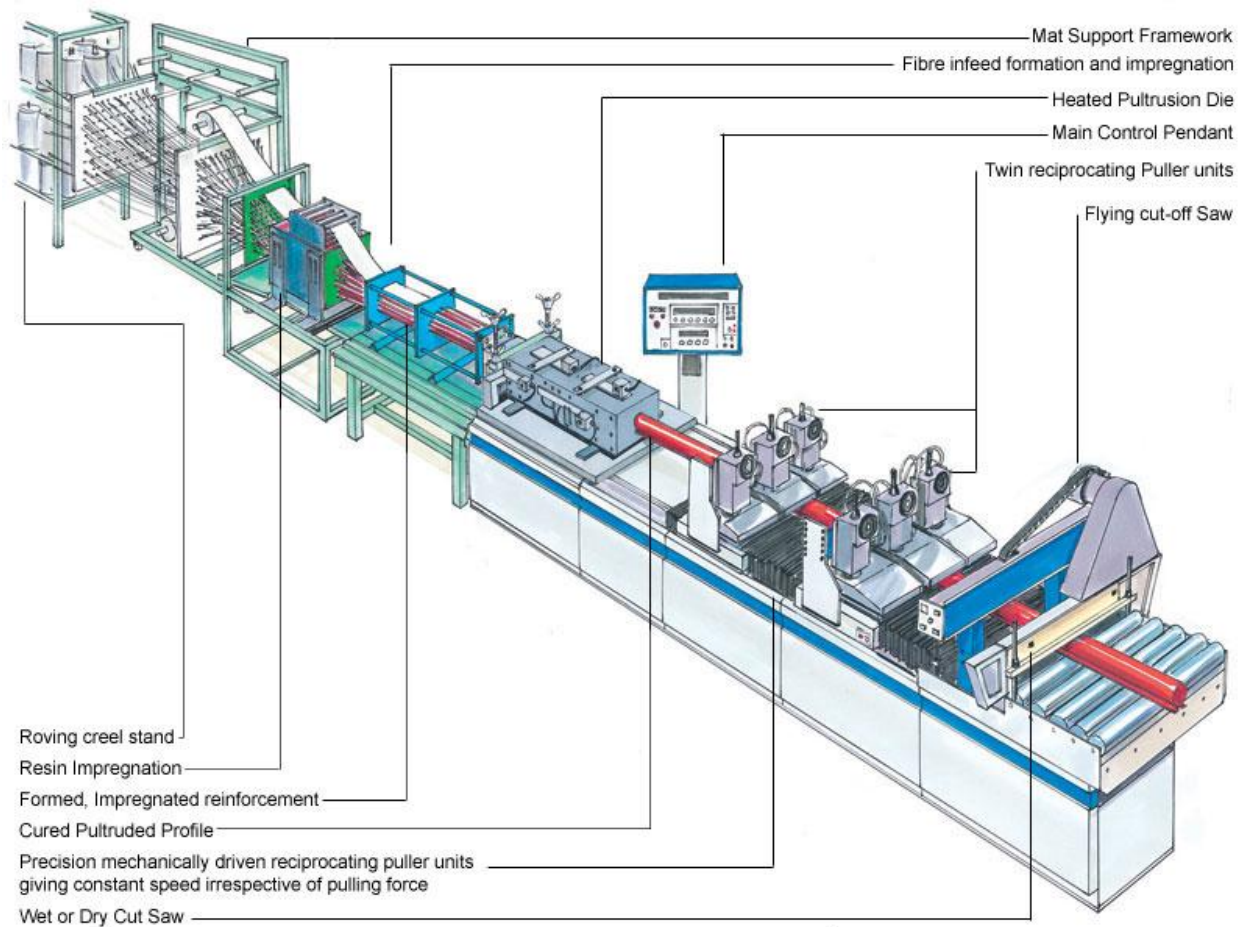
- Rotational molding offers design advantages over other molding processes.
- With proper design, parts assembled from several pieces can be molded as one part, eliminating high fabrication costs.
- The process also has inherent design strengths, such as consistent wall thickness and strong outside corners that are virtually stress free.
- For additional strength, reinforcing ribs can be designed into the part. Along with being designed into the part, they can be added to the mold.

### **Limitations**

- Rotationally molded parts have to follow some restrictions that are different from other plastic processes. As it is a low pressure process, sometimes designers face hard to reach areas in the mold. Good quality powder may help overcome some situations, but usually the designers have to keep in mind that it is not possible to make some sharp threads used in injection molded goods. Some products based on polyethylene can be put in the mold before filling it with the main material. This can help to avoid holes that otherwise would appear in some areas. This could be also achieved using molds with movable sections.
- Another limitation lies in the molds themselves. Unlike other processes where only the product needs to be cooled before being removed, with rotational molding the entire mold must be cooled. While water cooling processes are possible, there is still a significant down time of the mold. Additionally, this increases both financial and environmental costs. Some plastics will

degrade with the long heating cycles or in the process of turning them into a powder to be melted.

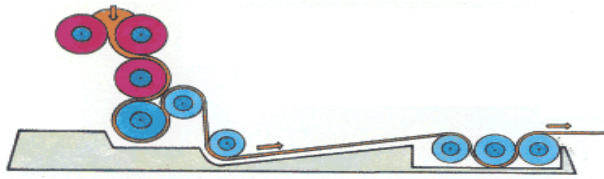
## Laminating



- In most cases, a hot laminator is used to seal the pouch and bind the layers together so that your document is laminated. The actual pouch consists of pockets of laminating film into which the item to be laminated is placed.

### Calendaring

- A PVC blend is pre-gelatinised and then kneaded to form a viscous material. It is laminated through a series of cylinders and transformed into a continuous sheet, which is cooled and then rolled up. The sheets may be mono-oriented during the process.
- As with extrusion, calendaring is a continuous process



- **Calendaring** is a finishing process used on cloth where fabric is folded in half and passed under rollers at high temperatures and pressures.
- Calendaring is used on fabrics such as moiré to produce its watered effect and also on cambric and some types of sateens.
- In preparation for calendaring, the fabric is folded lengthwise with the front side, or face, inside, and stitched together along the edges. The fabric can be folded together at full width, however this isn't done as often as it is more difficult. The fabric is then run through rollers that polish the surface and make the fabric smoother and more lustrous. High temperatures and pressure are used as well. Fabrics that go through the calendaring process feel thin, glossy and papery.