Blow Moulding

Blow moulding is a process of producing hollow or double wall objects from thermoplastic materials.

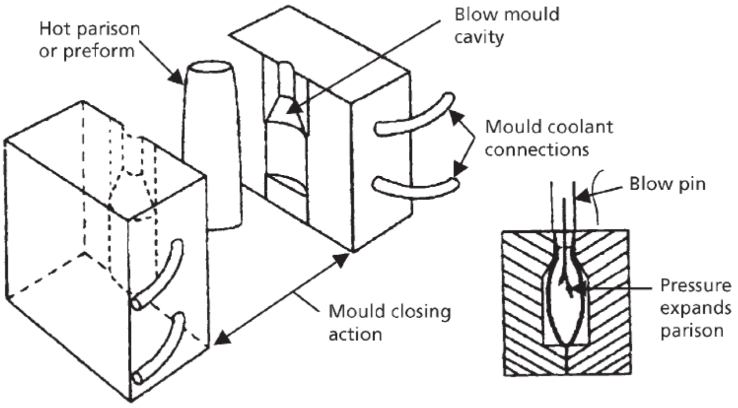
Basic Process

The basic process of blow moulding consists of three stages:

1. *Melting and Plasticising* – This is accomplished with either extrusion and/or injection moulding machine to produce the melt.
2. *Plastic Formation* – Through head and die or in an injection mould.
3. *Blowing and Moulding* – An auxiliary compressor provides air pressure and a clamp unit, which closes over a split mould that is operated with an hydraulic system.

Principle

The heated parison or preform is placed between two halves of the blowing mould, which closes and clamps around it. The heated tube is blown against the cavity wall and the molten plastic or resin takes the shape of the mould while being cooled. After the cooling stage the part is ejected from the mould. In the case of an extruded part it is necessary to remove the flash (excess plastic around the part) for further finishing.



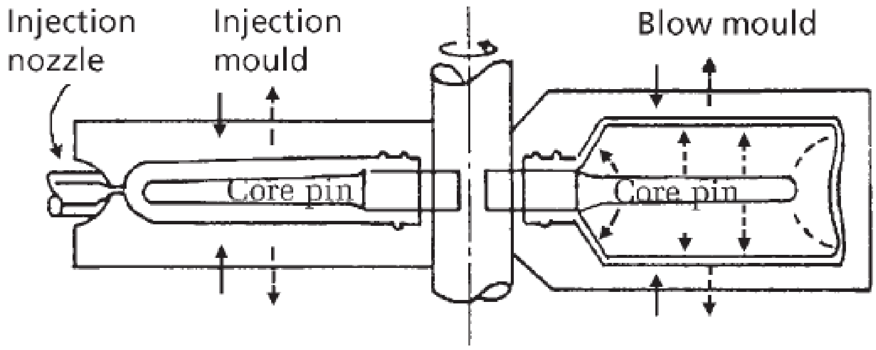
Basic blow moulding process

Types of Blow Moulding

Blow moulding may use either extrusion or injection methods for processing.

Injection Blow Moulding Process (IBM)

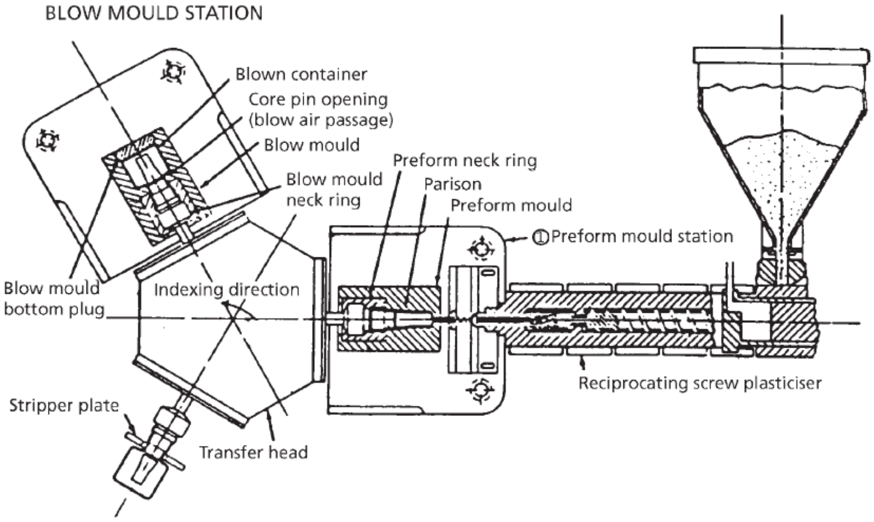
The term injection blow moulding is the compatible integration of two processes, injection moulding and blow moulding. It is a two-step process. The first stage consists of injection moulding the preform in a mould consisting of a cavity and a hollow core. The second involves moulding and cooling in a follow-on mould. The preform is injection moulded at a temperature which is in the temperature range of the moulding resin and blown at a temperature in the thermoplastic range. Injection blow moulding produces a parison with bottle neck and threads already formed to final dimensions. This method is preferred over extrusion blow moulding for making small parts that require high production volumes and closer quality dimensions.



Basic diagram of the injection blow moulding

Reciprocating Screw Machine

This is a combination of an injection and a plasticising unit in which an extrusion device with a reciprocating screw is used to plasticise the material. Injection of material into a mould can take place by direct extrusion into the mould, or by using the reciprocating screw as an injection plunger, or by a combination of the two.



Injection reciprocating machine

Advantages and Disadvantages of Injection Blow Moulding

Advantages of injection blow moulding are:

1. No scrap or flash to trim and reclaim
2. High quality neck finish and details
3. No process weight variation
4. Offers lowest part cost for high-volume bottles.

Disadvantages of injection blow moulding are:

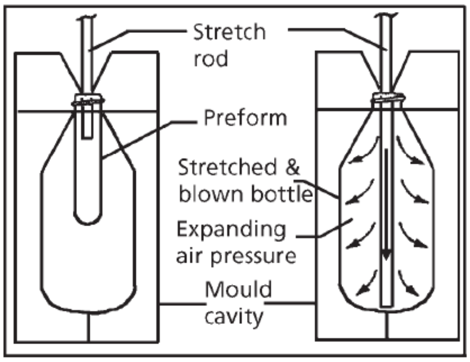
1. Tooling costs are higher than extrusion blow moulding
2. Bottle sizes and shapes are limited to an ovality ratio of 2:1 and a blow-up ratio of no greater than 3:1
3. Offset necks are possible but not handles.

Stretch Blow Moulding (SBM)

Stretch blow moulding became known in the blow moulding industry with the introduction of the soft drink bottle. 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 then when producing a container in another way.

Principle

Stretch blow moulding consists of conditioning (heating) a moulded and cooled preform to a specific temperature. The preform is closed in the blowing mould and is stretched in length and diameter.



A temperature conditioned preform is inserted into the blowmould cavity, then is rapidly stretched. Often a rod is used to stretch the preform in the axial direction with air pressure to stretch the preform in the radial direction.

Stretch blow moulding

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

1. 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.

2. 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.

Extrusion Blow Moulding (EBM) Process

Extrusion is the process of applying heat and pressure to melt the resin and force it through an accurately dimensioned die to produce the desired shape. For blowing purposes this is a shape from which the parison is cut. In contrast to injection blow moulding, all areas of the extruded parison, with the exception of the pinch off, undergo forming during the blowing step. This includes the closure threads on bottles and, in some cases, handles and support lugs.

Components of EBM

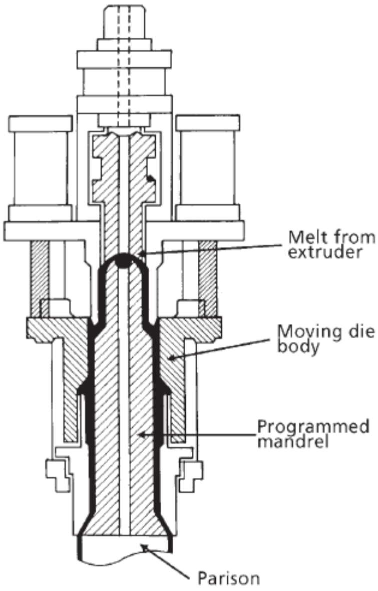
The Extrusion Blow Moulding Head and Die Unit

The function of the extrusion blow moulding head and die unit is to maintain the melt at a constant temperature and viscosity and to consistently form the parison at the desired rate and wall thickness.

There are two kinds of parison dies: centre-feed and side-feed.

Centre-Feed Die

In the centre feed die, the flow is vertically downward around the core. The main advantage of a centre fed die is that the melt flows uniformly downward all around the core. There is no reason for one part of the melt to flow faster than another. A disadvantage of the centre fed die is that the core must be supported inside the die head unit by either a perforated support or a 'spider' configuration. Both types of support cause flow lines (weld lines) in the parison, because the melt stream must split to pass around the solid portions of the support and then be rejoined. Flow lines can result in a blow moulded part with poor appearance and reduced strength in the area of the flow lines. Certain centre and side fed die designs, called spiral flow dies can greatly reduce or eliminate flow or weld lines in the parison and are widely used for this reason.



Centre feed die

Side-Feed Dies

With the side-feed die head, the melt flow enters at one side of the core and is guided around the core through channels to form a uniform tube to be extruded. There are no multiple weld lines, but it is more difficult to achieve a uniform rate of flow all around the die opening because a portion of the melt must pass around the core, while another portion flows directly to the die opening.

Wall Thickness control

Wall thickness around the circumference of the parison is adjusted by a set of screws at the die orifice. Control of the wall thickness along the length of the parison is possible with a suitably shaped die and a mandrel that can be moved axially within the die body.

Die and Mandrel

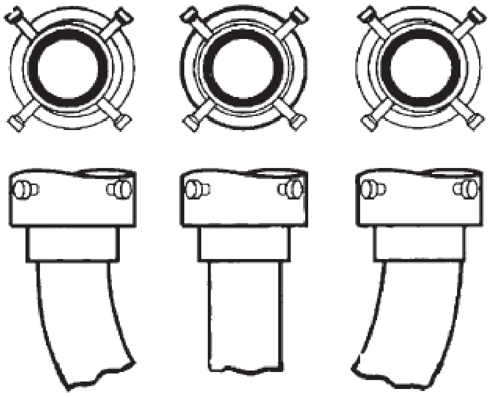
The die and mandrel (sometimes called a pin) are sized according to the desired parison diameter and wall thickness. At the die face, the melt should flow at a consistent rate all around the die to provide uniform wall thickness. The die land is the ring shaped (annular) section at the end of the die. It is also the working area where the volume is kept constant. The die land length should be between 10 to 40 times the die opening (or die slot) dimensions.

Die Swell

As the hot resin leaves the die opening, it swells, growing thicker but shorter. The term for this phenomenon is 'die swell', which is a bit of a misnomer since it is the hot plastic and not the metal die that does the swelling. The amount of swell depends on resin type, machine type, melt temperature, die head temperature, die design, and the rate of parison formation. The size and shape of the die opening or slot must be designed to compensate or correct for die swell.

Parison Adjustment

The purpose of the adjustment ring in a die head is to adjust for an uneven plastic flow from place to place around the parison. One cause is an off-centre mandrel, another is variations in melt or die surface temperatures or variations in the material. The adjustment ring is a movable ring at the base of the die head. It can be moved with the adjustment screws. Moving this adjustment ring changes the die head gap through which the plastic flows. If the melt flow through the die gap is uneven, the parison wall will be thicker on one side than on the other (as will be the blown part). This may cause the parison to curve or swing toward the hotter side, which will be the thicker side. To correct, that is to achieve even flow and uniform wall thickness, always tighten the adjustment ring screws on the side opposite the direction of swing.

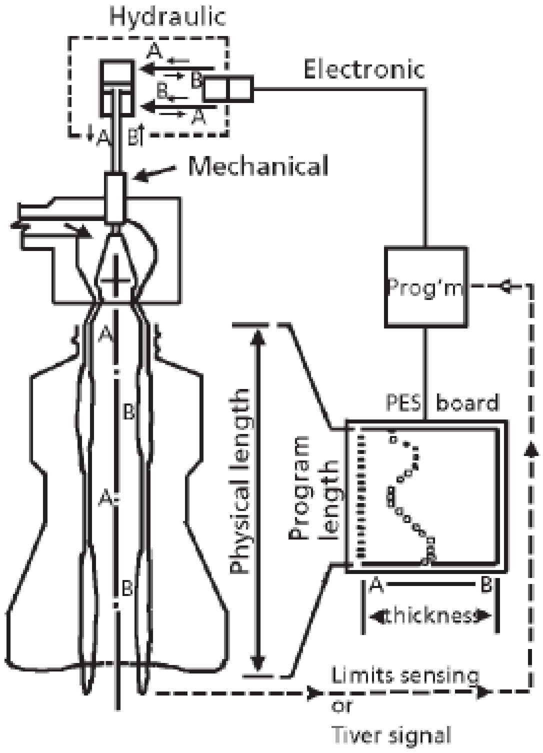


Head adjustment to achieve uniform parison wall gauge

Parison Programming

Unless the temperature is too high, the parison will stay in one piece as it is formed, but as it extrudes it is subject to gravity, and therefore thins out at the top. This thinning is referred to as sag, draw down, neck down, or stretch out. Such a parison (and final part) will end up being thicker at the bottom and thinner at the top, resulting in a part with non-uniform wall thickness. Parison sag is affected by the same factors as swell, that is, by resin type, machine type, melt temperature, die head temperature, die design, and the rate of parison formation. While swell and sag tend to work against each other, that is, the extrudate expands and shortens with swell while it thins and stretches with sag, the net result is usually a parison (and a final part) that is thicker at the bottom and thinner at the top. Sag becomes even more of a problem when parison formation takes a long time, since gravity has more time to act on the parison, resulting in more stretching and thinning.

When the parison reaches some 'critical length', it appears to be extruding faster, indicating that the upper part is stretching and thinning out. This condition can be overcome by gradually increasing the wall thickness during extrusion by moving the mandrel inside the die, a process called parison programming. It is done with an automatic timing device that raises the mandrel some predetermined distance at the proper time, to extrude more melt while the parison is being formed. When the mould closes, the mandrel returns to its original position.

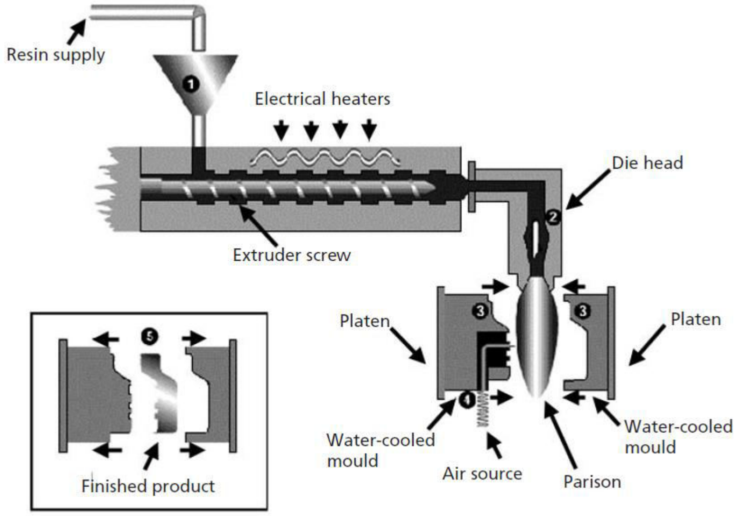


Parison programming

Parison programming can also be used to deliberately alter the wall thickness of the part in selected locations. By moving the mandrel up or down during extrusion, parison wall thickness can be increased or decreased to compensate for irregular part configurations in addition to sag. The die head gap distance is the most important factor affecting the parison wall thickness. Modern parison programming devices use a microprocessor to control the up and down movement of the mandrel (controlling up to 100 points is common). A further method of controlling wall thickness is to vary the extrusion pressure through a fixed die opening by changing the screw rpm. Higher screw rpm increases pressure and increases melt output; lower rpm reduces pressure and output.

Blow-up Ratio

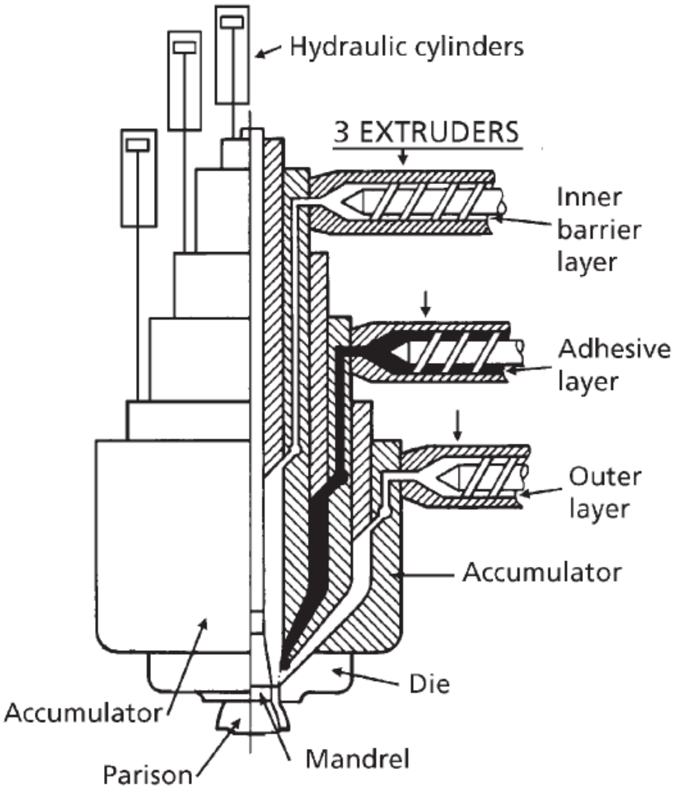
The blow-up ratio is defined as the ratio of the average diameter of the finished product to the average diameter of the parison. The maximum blow-up ratio for applications with a thick walled parison is 5:1. For most applications, 3:1 is preferable.



Cross section through extrusion blow mould machine

Co-Extrusion Blow Moulding

This term refers to products made with several layers in their wall structure and to the method of making them. These layers may be different materials, coloured or not coloured, recycled or virgin. This process makes it possible to combine materials of various properties to create a final product to meet the requirements of a particular application. The first commercial application of this process was a Heinz Ketchup (tomato sauce) bottle by the American Can Company in 1983. Currently, the automotive fuel tank is a typical application of this method (**Figure 1.10**). Combining layers in the die before finally extruding a parison creates the multilayered structure of co-extruded products. See multi-layered head.



Multi layered die head

Advantages and Disadvantages of Extrusion Blow Moulding

Advantages of extrusion blow moulding are:

1. Natural process for containers and hollow parts
2. Preferred process for high volume containers

Disadvantages of extrusion blow moulding are:

1. Uneven wall thicknesses
2. Close dimensional tolerances are difficult to achieve
3. Relatively low accuracy of surface finishing details.

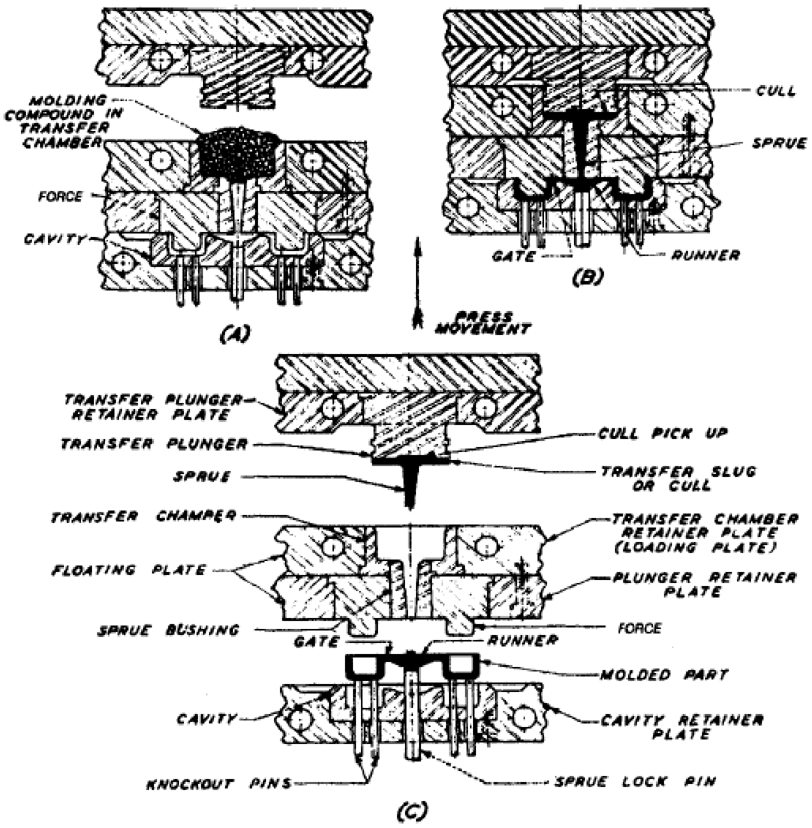
TRANSFER MOLDING PROCESS

The term "transfer molding" is applied to the process of

- forming articles, in a closed mold,
- from a thermosetting material that is conveyed under pressure,
- in a hot, plastic state, from an auxiliary chamber, called the transfer pot,
- through runners and gates into the closed cavity or cavities.

Description of Process

This type of molding requires the transfer of material under pressure from a "pot" or "well" through runners and gates into cavities retained in a closed heated mold (see below figs). Usually, the charge has been preheated before being placed in the pot. With preheating, less pressure is required for transfer, and the mold cycle time and mold wear are reduced.



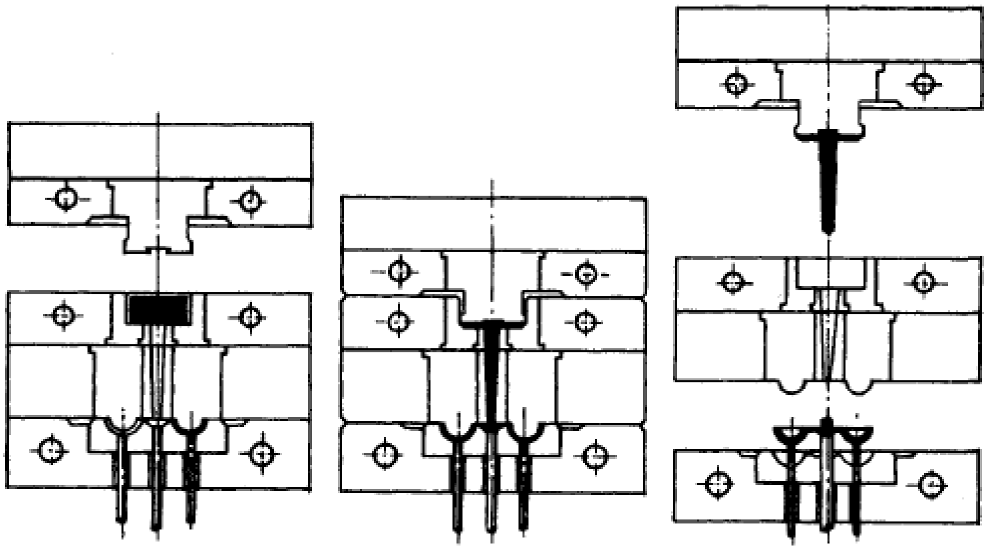
True transfer or pot-type transfer molding, the forerunner of today's common "plunger" or conventional transfer molding.

Basically, there are three variations of this technique.

Transfer Mold in Compression Press.

1. With this type, a single, hydraulic ram is used.
2. The plunger for the pot is clamped to the upper platen of the press.
3. Pressure is developed in the pot by the action of the main hydraulic ram of the press.
4. The area of the pot should exceed the area of the cavities by a minimum of **10%.**
5. Thus, the wedging action of the material will not force the mold cavities to open and flash.
6. Pot-type molding often is a manual operation.
7. This method is usually faster than compression molding, as the cure time, particularly for thick sections, often is shorter because the preheated material is introduced into the cavity at high speed through a restricted gate, imparting considerable mechanical shear to the flowing compound with resultant frictional heat.

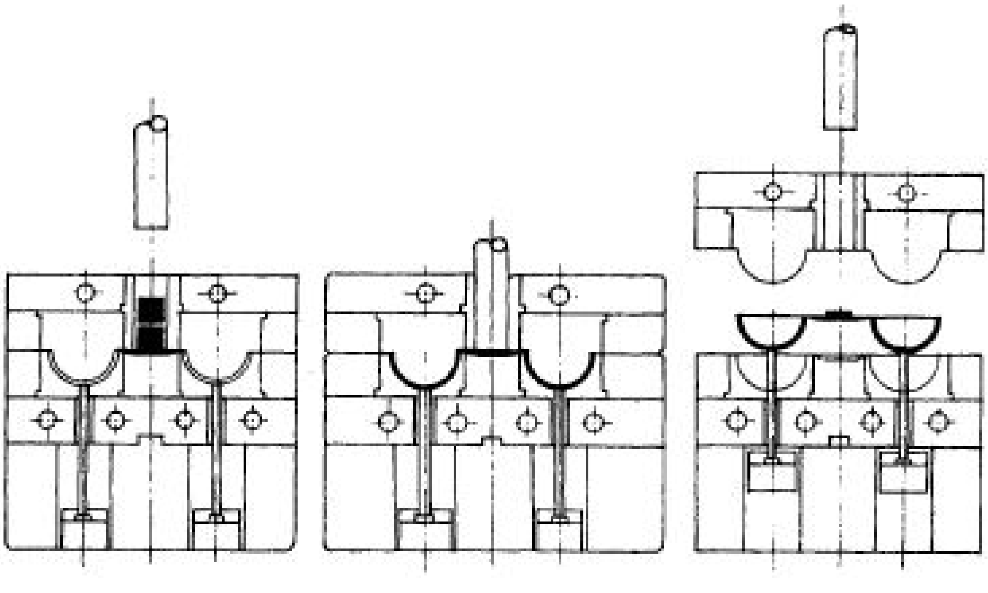
8. The sharp increase in temperature throughout the material charge enables rapid curing of molded parts with good dimensional control and uniform density.
9. The mold cost for transfer molding usually is higher than for compression molding, however, and the process is not well suited to automatic operation.
10. A three-plate mold is used with the ram or plunger in the top plate (Fig. below**)**.
11. Because the material enters the cavity at a single point, orientation of any fibrous filler is produced in a direction parallel to the flow.
12. The shrinkage of the molded part parallel to the line of flow and the shrinkage at right angles to the line of flow thus may be different and rather difficult to predict, depending upon the geometry of the molded part and the position of the gate.
13. When a transfer mold is opened, the residual disc of material left in the pot, known as the cull, and the sprue (or runner from the pot into the cavities) are removed as a unit.
14. To remove the molded part from the bottom section of the mold, ejector pins generally are used on the parts as well as on the runners.
15. In pot-type transfer, the taper of the sprue is the reverse of that used in injection molding because the goal is to keep the sprue attached to the cull so that it will pull away from the part.



Molding cycle of a transfer mold. Material is placed in the transfer pot (left), then forced through an orifice into the closed mold (center). When the mold opens (right), the cull and sprue are removed an a unit, and the part is lifted out of the cavity by ejector pins.

Plunger Molding

1. Sometimes called auxiliary ram transfer, plunger molding is similar to transfer molding except that an auxiliary ram is used to exert pressure on the material in the pot in this method.
2. This forces the preheated material through runners into the cavities of the closed mold.
3. A two-plate mold is used. Generally this type of molding is a semiautomatic operation with self-contained presses.
4. Basic steps of this process are similar to those of the pot or transfer molding method.
5. When the plunger is withdrawn and the mold opened, the molded part may be removed from the cavity with the runners and cull still attached as a unit.
6. The overall molding cycle in plunger molding usually is shorter than for transfer molding because removal of the sprue, runners, or cull does not require a separate operation.
7. In plunger molding, it is essential that radio frequency preheated preforms be used to take maximum advantage of the fast cures obtainable.
8. The below figure illustrates this process.
9. The mold temperature and pressure required to obtain a satisfactory molded piece must be predetermined for each type of thermosetting material used.
10. A detailed plunger mold is shown in below Fig.



Plunger molding. An auxiliary ram exerts pressure on the material in the pot (left) and forces it into the mold (center). When the plunger mold is opened (right), the cull and sprue remain with the molded piece

Screw-Transfer Molding

1. In this process, the material is preheated by preplasticizing in a screw and is dropped into the pot of an inverted plunger mold mounted in a downward clamping press with fixed bottom platen.
2. The preheated material is transferred into the mold similarly to plunger method.

The screw transfer process and the sequence of operation are shown in below Figs.

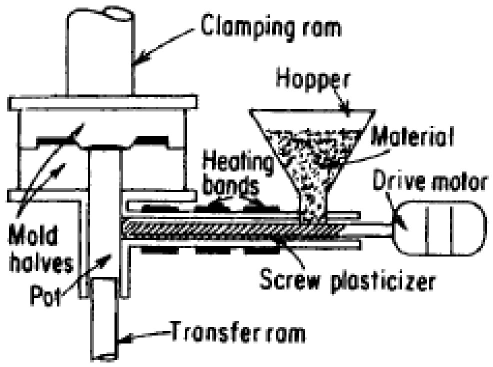
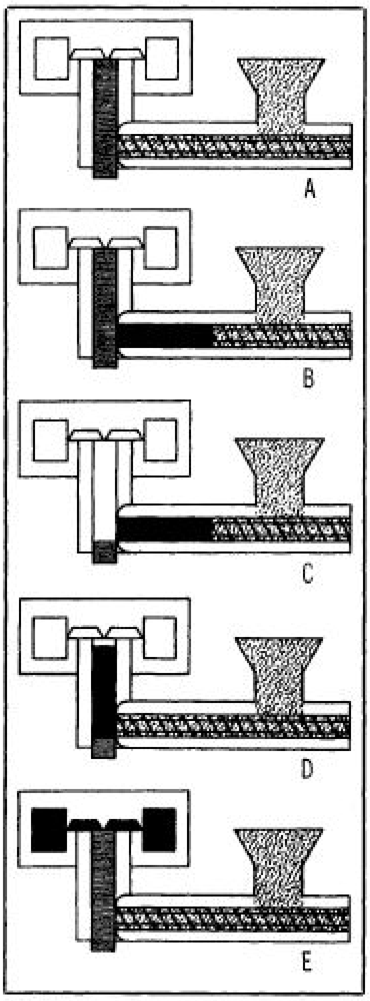


Fig. 9-16. Screw-transfer process.



Screw-transfer sequence. In A, the material is preplasticized as it travels along the flights of the screw. In B, material builds up to the end of the screw and forces it to move backward a predetermined distance. In C, after the shot is formed, the transfer ram lowers to open th transfer pot. In D, the screw moves forward to push the material into the transfer pot. In E, the transfer ram then advances through a standard bottom-transfer molding operation to inject the material into the mold.

1. In the screw-transfer process, thermosetting material is gravity-fed from a larger storage hopper through a hole in the barrel to the reciprocating screw preplasticizer.
2. As the screw rotates, material travels forward along the flights and is thoroughly preheated by mechanical shearing action.
3. The material flows off the end of the screw and begins to accumulate.
4. This buildup of material pushes the screw back along its axis (away from the transfer pot) to a predetermined point, which can be set by a limit switch.

5. The amount of reverse travel of the screw establishes the volume of the charge. While the shot is being preplasticized, the transfer ram is in the raised position, blocking the opening into the transfer pot.
6. After the shot is formed, the transfer ram returns to its lower position, leaving the opening to the transfer pot completely clear.
7. At this point, the screw moves forward, pushing the preheated material into the transfer pot. With the press closed, the transfer ram advances, delivering the preplasticized material to the runners and cavities.
8. This molding technique lends itself particularly well to fully automatic operation.
9. Screw-transfer presses are equipped with screw units capable of preparing from 85 grams to 2.5 kg shots.

To provide adequate control of preheating of the material in the screw units, certain requirements are necessary.

10. The **compression ratio** (ratio of shallowest to deepest depth of flight) for a thermoset screw transfer is much less than the ratio for screws available for thermoplastic materials.
11. The length-to diameter screw (L/D) ratio, in most cases, is considerably shorter.
12. Because of the exothermic reaction of most thermoset resins, a means to carry away heat generated in the barrel also is provided.
13. Aluminum water jackets surround the barrel, permitting the circulation of water.
14. The temperature of this water is regulated by separate control units.
15. Normally, one water control unit is provided for each temperature zone of the barrel.
16. Some machines even are provided with plasticizing screws that are channeled to permit the circulation of controlled-temperature water.
17. The object of the plasticizing units is to prepare material as hot as possible without precuring the resin.
18. Variables such as the water temperature of the barrel jackets, screw rotational speed, and back pressure applied to the screw as it prepares the material serve to control the amount of heat input to the material.

Advantages of Transfer Molding

Molding Cycles

1. Loading time usually is shorter in transfer molding than in compression molding, as fewer and larger preforms are used.
2. They can be preheated most rapidly and effectively in dielectric equipment.
3. In entering the mold, the material flows in thin streams through small runners and gates. This promotes heat transfer, and may also momentarily add some heat to the material through friction and mechanical work.
4. All of these factors contribute to substantially shorter molding cycles than are possible in compression molds, without preheating.

Tool and Maintenance Costs

1. Deep loading wells are not necessary with transfer molds, and mold sections can be thinner than in compression molds because they are not required to withstand the higher stresses involved during closing of the latter. This difference obviously permits an initial savings in tool costs.
2. There is less wear on the mold in transfer molding and much less tendency toward breakage of pins.
3. Transfer molds retain their original accuracy and finish considerably longer than do compression molds.

Molding Tolerances

1. Because the articles are produced in closed molds which are subjected to less mechanical wear and erosion by the molding material than are compression molds, closer tolerances on all molded dimensions should be possible in transfer molding.
2. This is particularly true of dimensions perpendicular to parting lines, because of the very small amount of flash in properly designed and operated molds of this type.
3. Also, it should be possible to hold closer tolerances on diameters of holes and dimensions between holes because forces in the mold that tend to distort or displace pins or inserts are much less in transfer molding.

Finishing Costs

1. Transfer molding reduces the costs of finishing all thermosetting materials.
2. In a transfer-molded article, a properly designed mold with adequate clamping pressure, the flash is quite thin or altogether absent.

3. Gates, except in certain cases with fabric filled phenolics, usually can be made sufficiently thin and can be so located that their removal is easy and inexpensive.
4. It may be possible to gate into a hole in the molded piece and to remove the gate by drilling.

Limitations of the Process

As might be expected, there are certain inherent limitations in transfer molding, are discussed below.

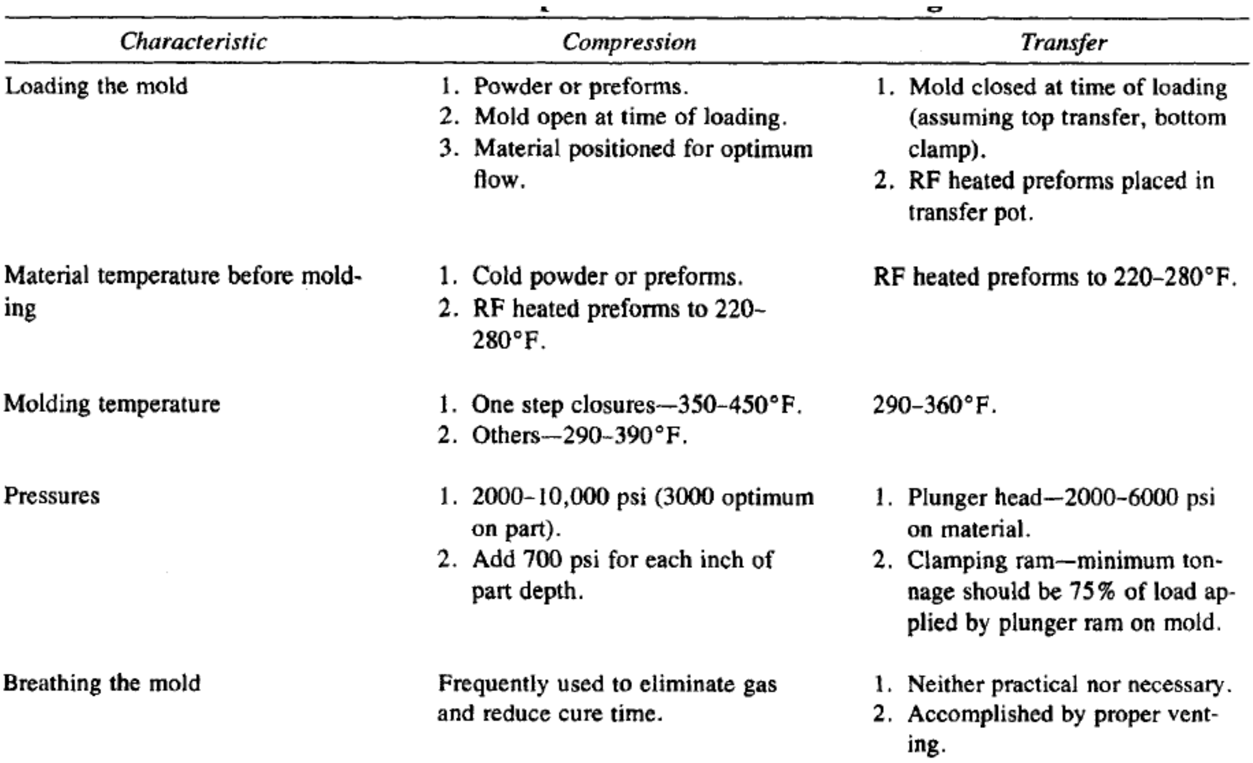
Mold cost

1. Molds are very expensive than compression molds.

Loss of Material

1. The material left in the pot or well (the cull), and also in the sprue and runners, is completely polymerized and must be discarded.
2. This loss of material is unavoidable, and for small articles it can represent a sizable percentage of the weight of the pieces molded.
3. In the auxiliary-ram molds, the cull is reduced to a minimum, and the main sprue is eliminated.

Comparison between Compression and Transfer Molding



Characteristic	*Compression*	*Transfer*
Loading the mold	1. Powder or preforms. 2. Mold open at time of loading. 3. Material positioned for optimum flow.	1. Mold closed at time of loading (assuming top transfer, bottom clamp). 2. RF heated preforms placed in transfer pot.
Material temperature before molding	1. Cold powder or preforms. 2. RF heated preforms to 220–280°F.	RF heated preforms to 220–280°F.
Molding temperature	1. One step closures—350–450°F. 2. Others—290–390°F.	290–360°F.
Pressures	1. 2000–10,000 psi (3000 optimum on part). 2. Add 700 psi for each inch of part depth.	1. Plunger head—2000–6000 psi on material. 2. Clamping ram—minimum tonnage should be 75% of load applied by plunger ram on mold.
Breathing the mold	Frequently used to eliminate gas and reduce cure time.	1. Neither practical nor necessary. 2. Accomplished by proper venting.

Cure time (time pressure is being applied on mold)	30–300 sec—will vary with mass of material, thickness of part, and preheating.	45–90 sec—will vary with part geometry.
Size of pieces moldable	Limited only by press capacity.	About 1 lb maximum.
Use of inserts	Limited—inserts apt to be lifted out of position or deformed by closing.	Unlimited—complicated. Inserts readily accommodated.
Tolerances on finished products	1. Fair to good—depends on mold construction and direction of local flow of material during final closing. 2. Flash—poorest. Positive—best. Semipositive—intermediate.	Good—close tolerances easier to hold.
Shrinkage	Least.	1. Greater than compression. 2. Shrinkage across line of flow is less than with line of flow.

TROUBLESHOOTING

Problem	Possible Causes	Possible Solutions
Short molding (all powder cleared from pot)	Insufficient molding powder	Increased charge to pot.
Short molding (cull left in pot)	Insufficient flow of material caused by incorrect temperature; insufficient pressure; flow of powder too stiff; or gates and runners too small	Check and adjust temperature to proper range; check and adjust to proper pressures; use freer flowing powder; increase sizes of gates and/or runners.
Blisters or soft molding	Undercured	Increase cure time.
		Increase mold temperature.
Blisters or soft molding	Undercured	Preheat material.
Excessive flash	Transfer pressure too high	Reduce pressure or increase locking force.
Gas marks	Trapped gas–particularly with UF material	Preheat material prior to charging pot.
Burn marks	Air trapped in mold	Arrange for proper venting of mold.
	Pot or mold temperature too high	Reduce temperature.
	Molding cycle too long	Reduce time cycle.
Precure	Preheating temperature too high	Reduce time or temperature of preheating, use radio frequency heating, reduce power input.
	Mold or pot too hot	Reduce temperature.
	Time of dwell in pot too long before flow commences	Apply pressure sooner after charging pot.
Ripples or orange peel	Uneven flow in mold	Use a freer flowing powder and pre-heat.
		Apply pressure more slowly and thus reduce jetting.