

PRINCIPLES OF THERMOSET PLASTICS MOLDING

1. Thermosets, when placed in a heated mold under pressure, will conform to the shape of the mold and cure into a hard infusible product.
2. Thermosetting molding compounds (thermosets) that undergo a chemical reaction or cure (called polymerization or molecular growth) during the molding operation.
3. Successful plastics molding is dependent on good mold design and construction, the mold temperature, material temperature, molding pressure, etc.
4. All of the thermoset compounds, except epoxies and silicones, may be molded by the following methods:
 1. compression, transfer, thermoset injection, and the runnerless injection/compression process.

Mold temperature.

1. Thermoset molding compounds may be molded in a temperature range of 141-204° C.
2. Material suppliers should be consulted for recommended temperatures for a specific material and molding method.
3. Molds may be heated by steam, hot oil, electric cartridge or strip heaters, or any combination of these.

Material temperature.

1. Minimum cure time is a function of increased mold temperature and maximum material temperature when loaded in the mold.
2. It is desirable to preheat most compounds.

Molding pressure.

1. The pressure causes the compound to flow within the confines of the mold cavities and forces it to completely fill out the part with minimum flash thickness.
2. The required pressure is dependent on the method of molding.

PRINCIPLES OF COMPRESSION MOLDING

1. In compression molding, the thermoset compound is placed in the open heated mold.
2. The material may be in powder form or as a preform.
3. As the mold closes, the heat and pressure cause the material to flow, compressing it to the required shape and density as defined by the mold.
4. Continued heat and pressure produce the cure that hardens the material.

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5. The thinner the part, the shorter the cure; conversely, thicker pieces take longer to cure.
6. Part design should have as uniform a wall thickness as possible.

Molding Equipment

1. The mold is fastened in a vertical molding press, either up-acting or down-acting, usually hydraulically driven.
2. They have provision for an ejection system for the parts, usually both up-acting and down-acting.
3. The press operation may be either automatic or semi-automatic, in sizes up to 2000 tons

Auxiliary Equipment

1. Preform presses, high-frequency preheaters are commonly used as auxiliary equipment.

Preform presses.

1. These are either hydraulic or mechanically operated, with various die sizes and shapes to squeeze the material in the cold state into a preform or briquette of the exact charge weight required.
2. These presses work automatically.

High-frequency preheaters

1. Heat the preforms in the 93–149°C range so the molding material is ready to flow as soon as it is loaded into the heated mold.

Compression Molding Process

1. The mold consists of two halves, one containing the cavity or cavities (the female section) and one containing the force or forces (the male section).
2. Each is mounted on press supports or grids which are in turn fastened to the stationary or moving platens.
3. Generally, the cavities are in the lower half to permit easy loading of the molding compound.
4. This operation may be manual or automatic.
5. In the case of automatic operation, movable loading trays are incorporated, in conjunction with trays or forks to receive molded parts from the mold.
6. A predetermined amount of molding material is placed into the open mold.
7. By closing the mold and compressing the material, the desired shape is achieved.

8. Both thermosets and thermoplastics may be compression molded; the process is used mostly for thermosets and thermoplastics containing significant amounts of fillers which reduce their viscosity (flowability), required for injection molding. (Examples: phenolics with up to 60% mineral fillers, for insulators; polysulfones up to 80% ceramic, for engineering uses.)
9. Flashing (Breathing) is necessary to allow the air or gases to escape.
10. The cure duration is dependent on the type of molding compound, mold temperature, pressure on the material, and material temperature.
11. Cross-sections (3.18–12.7 mm) thick may cure in 30 seconds–2 minutes when preheated material is used (which is always desirable).
12. For thermosets, the material can be cold, but more often it is preheated close to the “setting” temperature.
13. The mold is heated using steam or electric heaters, and remains closed until the part is “cured” or “set”; the hot part is then ejected.
14. Products produced are tires, components for the electrical industry, dinnerware, and under-the-hood automotive parts.

Compression Molding Cycle

A typical cycle, with the mold at recommended temperature and with adequate pressure available, would proceed as follows:

1. Air-clean the mold of all flash or foreign matter.
2. Load the material into the cavities.
3. Close the mold completely; or before closing it, interject a brief “breathe cycle” by opening the mold slightly to release any air and gases trapped in the molding compound.
4. Complete the cure time.
5. Open the mold and activate the knock-out assembly.
6. Remove the molded parts.
7. Clean the mold with an air blast.

Compression Molding of thermoplastics

1. For thermoplastics, the hot (melted) material is placed into the relatively cold mold;
2. the mold closes and compresses the material into the desired shape.
3. When the part has cooled down enough to be handled without deformation, it is ejected.

General consideration

1. With the materials processed by compression molding, the mold is open while the material is loaded.
2. During the closing, it is unavoidable to have excess material escape at the parting line (flash).
3. It is necessary to provide an excess of material with every shot, which is wasted (scrap) with thermosets, but can be reused with thermoplastics.
4. In either case, the flash must be removed to provide a finished part, either by tumbling manually (parts permitting) or mechanically.

Molding Conditions

Factors to be considered during compression molding are the type of molding compound, the mold temperature, and the molding pressure.

Compound.

1. When using a molding compound with the desired functional performance characteristics, the specifications should provide a bulk factor not greater than 3:1 (solid to liquid ratio), good funnel flow rating, and proper plasticity.

Temperature.

1. As stated previously, temperatures range from 285–400° F (141–204° C).
2. The mold temperature should be specified by the material supplier.

Pressure.

1. Generally, all thermoset compounds recommended for compression molding require the same molding pressure.
2. Polyesters are the exception and are considered low-pressure materials.
3. Epoxy and silicone materials are not generally molded by compression.
4. A material of recommended plasticity, at room temperature, requires pressures of 13.8–20.7 MPa on the projected molding and land area of each cavity.
5. Parts greater than 25 mm in depth require an additional 4.1 Mpa per inch of depth.
6. Preheated material may reduce pressures 50% or more.

Mold Construction

Factors influencing mold construction include the mold cavity and forces, and the materials and method of construction.

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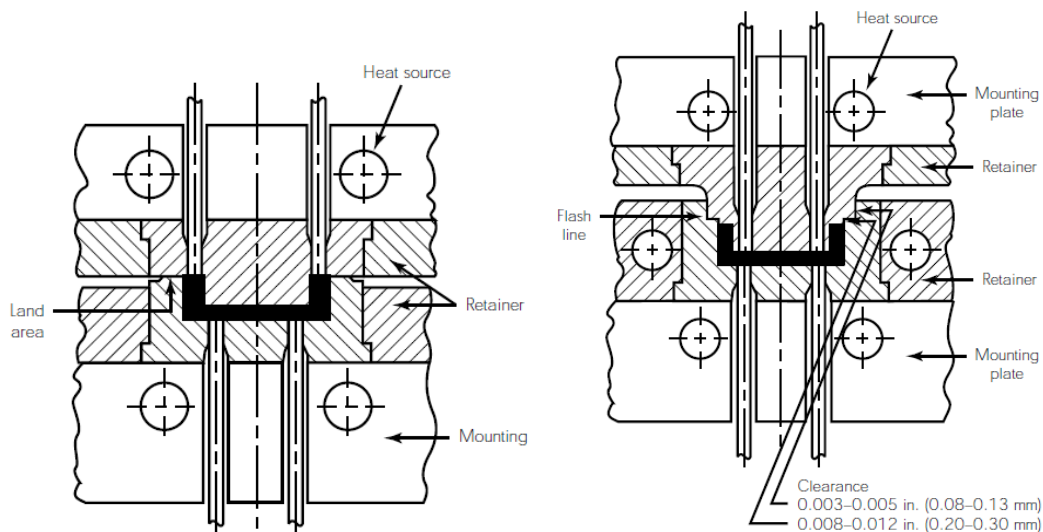
Cavity and forces. The molds may contain a single cavity or multicavities. The number of cavities is determined by the production requirements, part size, type of material, and clamp capacity of the molding press.

Determining factors that dictate design of the mold cavity and operational force include the type of material, part design, flash-line restrictions, part dimensions and tolerances, and end-use requirements. Shrinkage of material during curing and cooling is built into mold dimensions.

Mold types. Five basic types of compression mold cavity and force are available for selection:

Flash type. The flash-type mold, illustrated in below figure, is simple in construction and low in cost. Disadvantages are that it creates minimal back pressure within the cavity (needed to control density and molded part dimensions) and it has high flash scrap loss. The flash mold is not recommended for parts requiring maximum density and strength.

Semipositive, vertical-flash type. The semipositive, vertical-flash type mold, shown below figure, requires double fitting of force to cavity and is costly. It controls maximum density and critical dimensions as related to cavity and force, offers ease of flash removal on large parts, and leaves no flash line scar on the side of the part.

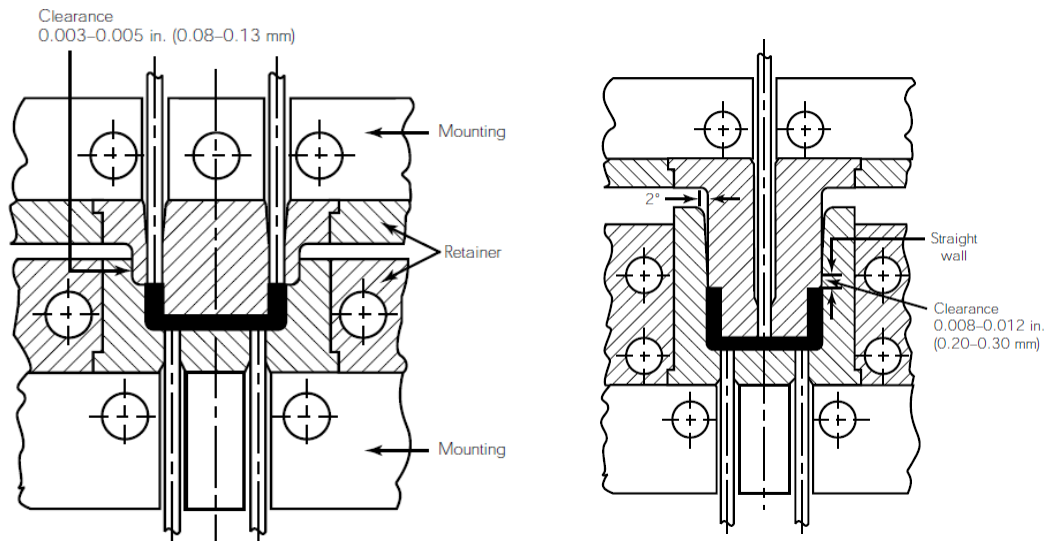


Flash type

Semipositive, vertical-flash type

Semipositive, horizontal-flash type. The semipositive, horizontal-flash- type mold, shown in below figure, controls conditions in a manner similar to that of the vertical-flash type, but it is less costly and more popular. It is recommended for close-tolerance parts and assures minimum flash finish.

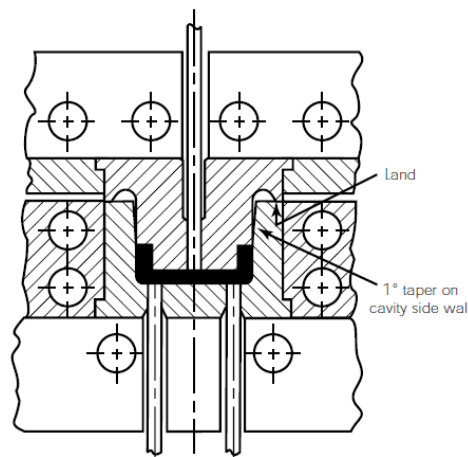
Direct-positive type. The direct-positive-type mold, illustrated in below figure, is used for high-bulk materials and deep-draw parts when maximum density is required. It is a single-cavity mold that uses an accurately weighed charge of material.



Semipositive, horizontal-flash type

Direct-positive type

Landed-positive type. The landed-positive type mold, shown in below figure, is used as a single-cavity mold on a rotary press. Molding pressure is controlled at each station. Maximum density may be maintained by clearance between the side wall of the force and the cavity. Overall height of the part is controlled by land areas on mating surfaces of the force and cavity.



Mounting and retainer plates. Cavities and forces are assembled on mounting plates and may be held in the confines of a retainer plate. Heat sources are contained in one or both units.

Part-removal systems. A top and bottom knockout system is necessary in automatic operations. One set of pins may act as hold down or hold-up pins while the second set facilitates part removal.

Mold design. Mold design is a special area and requires expertise in steel types and hardness specifications, machining methods, and other factors that may vary in the molds for producing different parts.

Mold making. The principal kinds of steel used for making plastics molds are prehardened, carburizing, oil hardening, air hardening, stainless, and maraging. These materials are supplied in rolled, forged, and cast sections. The primary methods used to form cavities in steel molds are conventional machining hobbing and electrical discharge machining (EDM). Heat treatment is part of the mold-making process, unless a prehardened steel is selected. Finishing of the mold cavity surface is usually done by grinding and polishing.

Applications

The following applications are representative of the market areas for which many parts are molded by compression:

- Wiring devices – wall plates, outlet boxes and receptacles, switches.
- Closures – bottle and tube caps for drugs and cosmetics.
- Electrical switch gear – home and low-voltage circuit breakers.
- Automotive parts – brake and transmission parts, grilles and body parts, ignition parts.
- Dishware – melamine dishware.
- Small appliances – knobs, handles, bases for motor mounts and cookers.
- Housings – sanitary tubs, stall shower units or bases, electrical outlet boxes.

TABLE 13-4
Common Faults, Causes, and Remedies in Compression Molding¹

Problem	Possible Causes	Possible Solutions
Pieces blistered	Molding cycle too short	Increase time of cycle.
	Air or gases trapped in mold	Close mold more slowly; provide sprue grooves to allow escapement of gas; preheat* material.
Pieces blistered	Material has absorbed water by exposure	Preheat* material.
	Mold too hot	Reduce temperature.
	Insufficient pressure	Increase pressure or adjust powder weights if multiple-cavity mold is used.
	Mold too cold	Increase temperature.
	Mold charge too bulky, contains too much air	Preform material, or distribute in most suitable manner to allow air to escape. If powder, arrange in a pile similar to a mountain peak, rather than a volcano.
	Nonuniform heating	Rearrange steam channels or place mold in press in a way to promote uniformity of heating.
Parting line porous but bottom and flash thick. Finish good where piece is properly filled out and pressure is directly on it	Piece designed with thick non-uniform walls	Tablet the charge; preheat* material; reduce molding temperatures.
	Material too “hard”, does not flow freely	Use a softer material.
	Pressure insufficient	Increase pressure.
	Mold too hot resulting in precuring	Lower temperature.
	Mold closed too slowly, resulting in precuring	Increase speed of closing by more rapid supply of pressure; pre-heat* material.
	Mold charge too great to allow proper escapement and closing of the mold	Adjust charges properly or provide sprue grooves for escapement.
Molded piece is flexible on discharge	Piece is insufficiently cured	Increase curing cycle; if temperature is too low, raise it.
	Material has absorbed water by exposure	Preheat* material.
	Too much lubricant used on mold, causing material to be plasticized	Reduce or do not use lubricant.
Molded piece sticks or adheres to mold	Temperature too high and resin fails to come to surface and cover it. (Common with mineral filled material.)	Reduce temperature.
	Mold fouled by improper lubricant or previous materials. Phenolic material will stick after cellulose acetate has been used when molds are not chromium-plated	Clean surface of mold and polish.
	Mold is undercut by scratches, dents, etc.	Repair mold.
	Mold is poorly polished	Polish mold.
	Mold is irregularly heated, leaving cold spots	Heat properly.
	Pieces are undercured—too short a cycle or too low a temperature	Increase cycle; increase temperature.

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Pieces warped	Mold heated nonuniformly	Correct heating methods.
	Material too soft	Use harder material and/or preheat* material.
	Insufficient cure	Increase cycle.
	Mold too hot, causing case-hardening of piece	Decrease temperature.
	Piece of irregular wall thickness and shape resulting in complex flow, cure, and shrinkage	Use lower shrinkage material; adjust temperature of various parts of mold accordingly; preheat* material and load hot; redesign piece to uniform section.
	Charge left too long in mold before closing	Close faster.
	Molding placed where it cools very unevenly; for example, on cold metal plate	Provide means for uniform cooling; provide shrink fixtures.
	Material has absorbed moisture due to exposure	Preheat* material and load hot or cold.
	Pieces cooled nonuniformly (one side cooling faster than the other after molding)	Cool uniformly.

Compression molding of thermosetting materials has certain advantages over transfer or injection molding, as follows:

1. Waste of material in the form of sprue, runners, and transfer-culls is avoided, and there is no problem of gate erosion.
2. Internal stress in the molded article is minimized by the shorter and multidirectional flow of the material under pressure in the mold cavity.
3. In the case of high impact types with reinforcing fibers, maximum impact strength is gained. This results because reinforcing fibers are not broken up as they are when forced through runners and gates in transfer and injection molding, and because fibers are more randomly positioned, as compared to the more oriented fibers resulting from flow into transfer or injection molds.
4. A maximum number of cavities can be used in a given mold base without regard to demands of a sprue and runner system.
5. Compression molding is readily adaptable to automatic loading of material and automatic removal of molded articles. Automatic molding is widely used for small items such as wiring device parts and closures.
6. This technique is useful for thin wall parts that must not warp and must retain dimensions.
7. Parts with wall thicknesses as thin as 0.025 inch are molded; however, a minimum wall thickness of 0.060 inch usually is recommended because thermosetting materials are brittle as compared to more resilient thermoplastics.
8. For parts weighing more than 1.5 kg, compression molding is recommended because transfer or screw injection equipment would be more expensive for larger parts.

9. For high-impact, fluffy materials, compression molding normally is recommended because of the difficulty in feeding the molding compound from a hopper to the press or preformer.
10. In general, compression molds usually are less expensive to build than transfer or injection types.

Limitations of Compression Molding

1. In the case of very intricately designed articles containing undercuts, side draws, and small holes, the compression method may not be practicable, because of the need for complicated molds and the possibility of distorting or breaking mold pins during the flow of the material under high pressure.
2. Articles of 0.35 inch or more thickness may be more advantageously made by transfer molding, particularly a thick article of small area, in which there is little flow. Thus, for a heavy handle, compression molding would be slower than transfer or injection.
3. In order to ensure complete filling out of the mold, it may be necessary to place the charge of plastic into an optimum position in the mold, and in some cases to use preforms of special shape. This is particularly important if the mold does not provide a means of confining the charge.
4. Polyester and alkyd compounds are particularly troublesome, and require positive means of confinement in order to fill the cavity completely.
5. It is necessary that mating surfaces or land areas, for the molds be cleaned between successive shots.
6. Also slight fins or flash must be expected on molded articles where the mold sections meet.
7. Another important consideration is the plastics' degree of rigidity at that point of final cure when ejection is to take place.
8. In some cases, compression molding of thermosetting material may be unsatisfactory for production of articles having extremely close dimensional tolerances, especially in multiplecavity molds and particularly in relation to nonuniformity of thickness at the parting line of the molded article. In such cases, transfer or injection molding is recommended.

Selection of Molding Method–Compression or Transfer		
Factors to Consider: Advantages–Limitations	Compression	Transfer
Close tolerances, projected area	•	
Close tolerances, over flash line, minimum flash		•
Lowest mold shrinkage	•	
Uniform shrinkage, all directions	•	
Maximum uniform density	•	
Reduced cure, thick sections		•
No weld lines, less molded-in strains	•	
Small holes, longer length, through holes		•
Extremely thin mold sections, telescoping		•
No venting problems	•	
Impact strength	•	
Molds with movable sections or cores		•
Molded-in inserts		•
Large projected area parts	•	
Lowest mold-flash scrap	•	
Generally less mold maintenance		•
Gate or sprue removal necessary		•
Maximum number cavities per clamp force	•	
Mold erosion, sprues, runners, gates		•
Generally higher mold cost		•