Department of Materials Engineering
General Materials Branch

Fourth Class

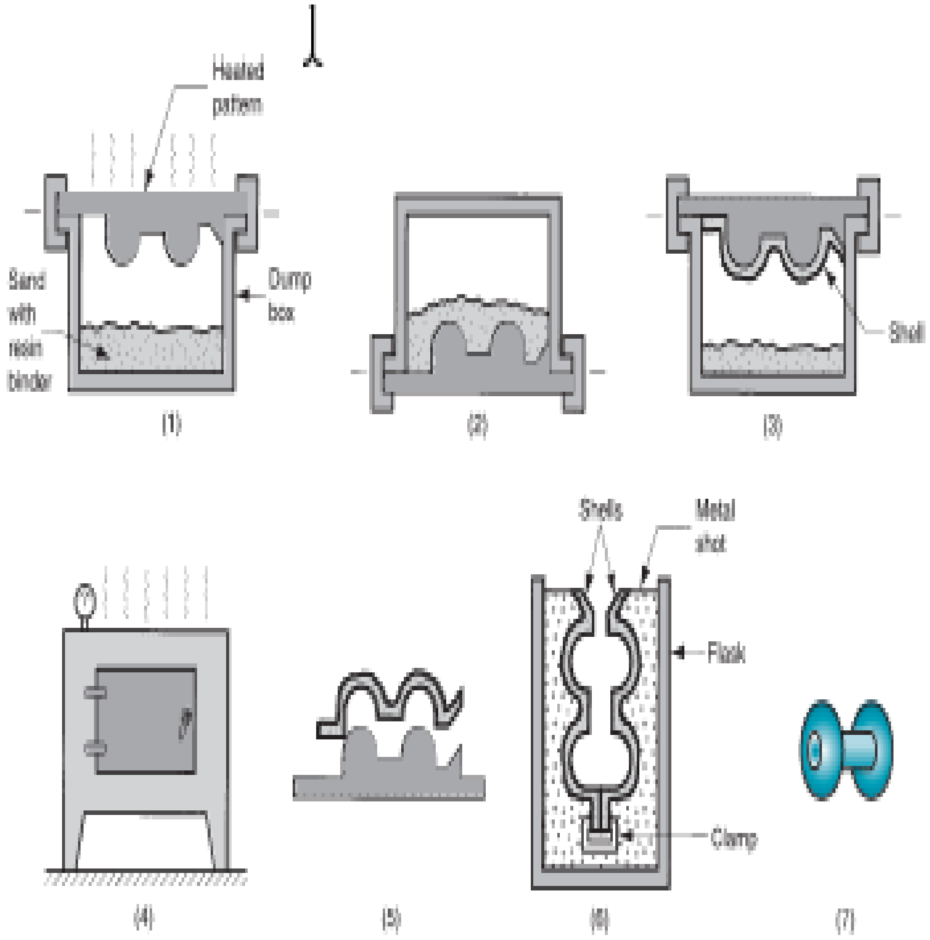
Casting Technology

Lecture Eight : Other Casting Processes

Class Code :ofp4npn

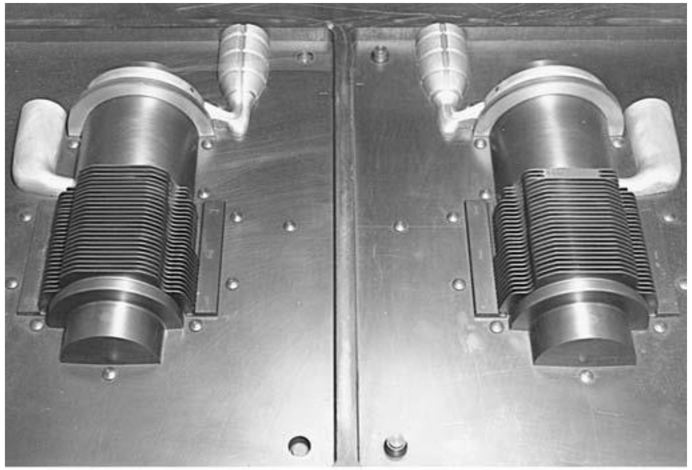
Shell Casting

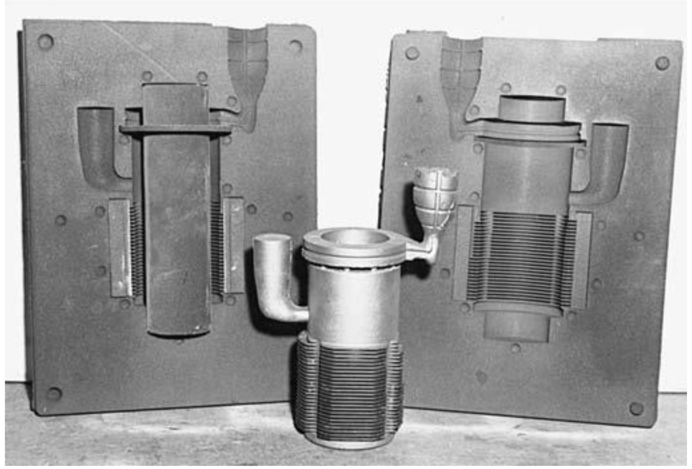
1. a match-plate or cope-and-drag metal pattern is heated and placed over a box containing sand mixed with thermosetting resin;
2. Box is inverted so that sand and resin fall onto the hot pattern, causing a layer of the mixture to partially cure on the surface to form a hard shell;
3. Box is repositioned so that loose, uncured particles drop away;
4. Sand shell is heated in oven for several minutes to complete curing;
5. Shell mold is stripped from the pattern;
6. Two halves of the shell mold are assembled, supported by sand or metal shot in a box, and pouring is accomplished.
7. The finished casting with sprue removed



Shell Casting

(Top) Two halves of a shell-mold pattern. (Bottom) The two shells before clamping, and the final shell mold casting with attached pouring basin, runner, and riser. *(Courtesy of Shalco Systems, Lansing, MI.)*





Binder Jetting in Shell Casting

- A typical part produced by BJP from ceramic powder is a ceramic-casting shell in which aluminum-oxide or aluminum-silica powder is fused with a silica binder.
- The molds are postprocessed in two steps:

1. curing at around 150◦C
2. firing at 1000◦ to 1500◦C.

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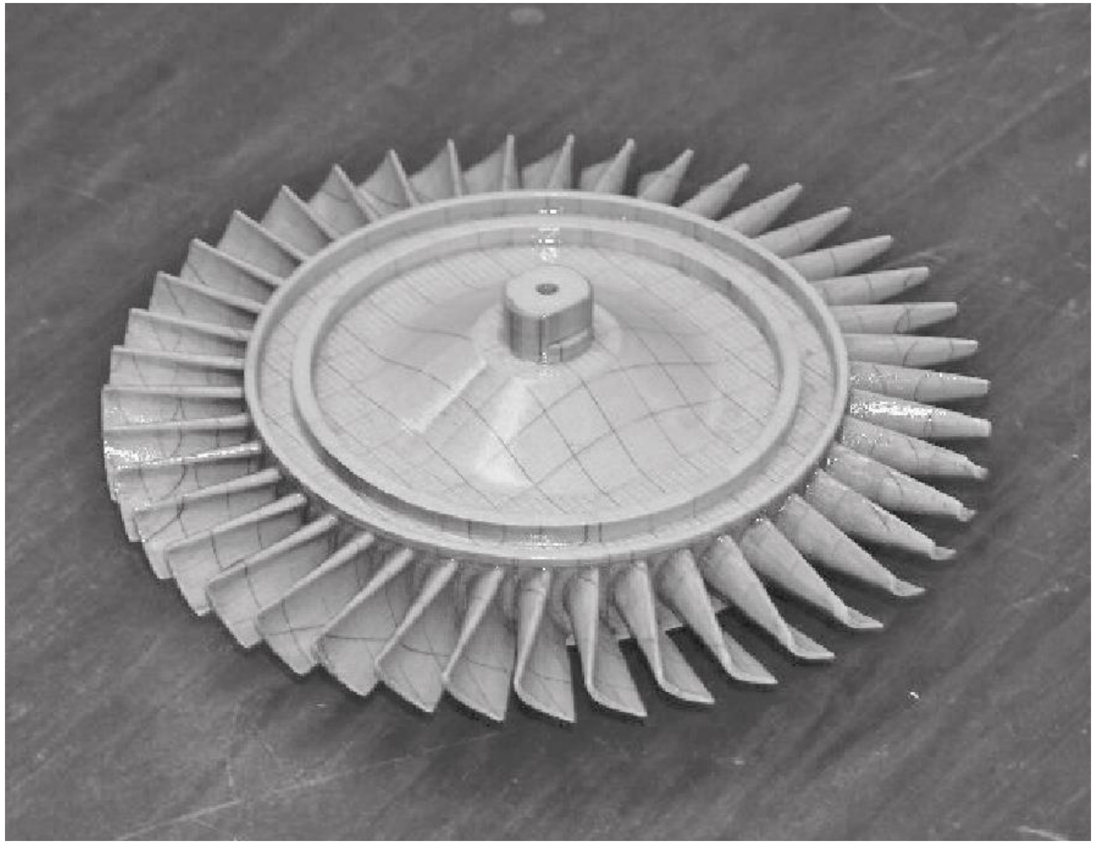


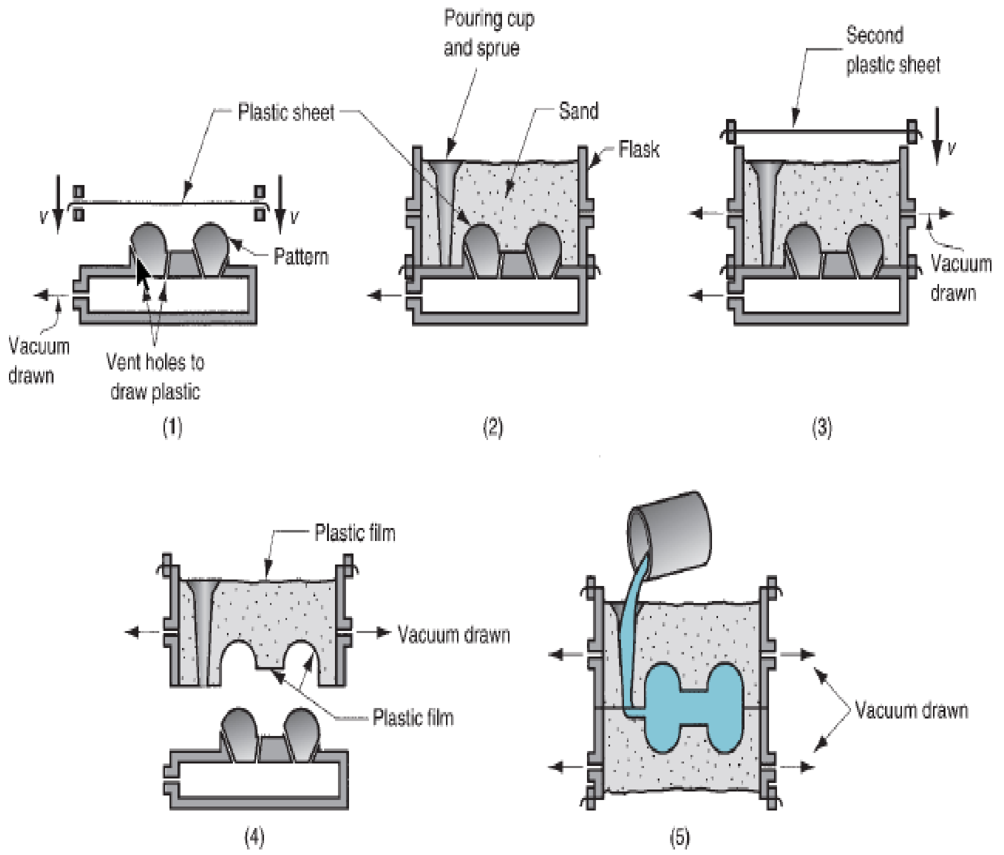
Shell Casting in Summery

- ***Process:*** Sand coated with a thermosetting plastic resin is dropped onto a heated metal pattern, which cures the resin .The shell segments are stripped from the pattern and assembled. When the poured metal solidifies, the shell is broken away from the finished casting.
- ***Advantages:*** Faster production rate than sand molding, high dimensional accuracy with smooth surfaces.
- ***Limitations:*** Requires expensive metal patterns. Plastic resin adds to cost; part size is limited.
- ***Common metals****:* Cast irons and casting alloys of aluminum and copper.
- ***Size limits:*** 30 g (1 oz.) minimum; usually less than 10 kg (25 lb.); mold area usually less than 0.3 m^2 (500 in^2).
- ***Thickness limits:*** Minimums range from 0.15 to 0.6 cm (to in.), depending on material.
- ***Typical tolerances:*** Approximately 0.005 cm/cm.
- ***Draft allowance:*** *0.25* or 0.5 degree.
- ***Surface finish****: 0.5* –4.0 microns (50–150 μin.) rms.

Vacuum Molding

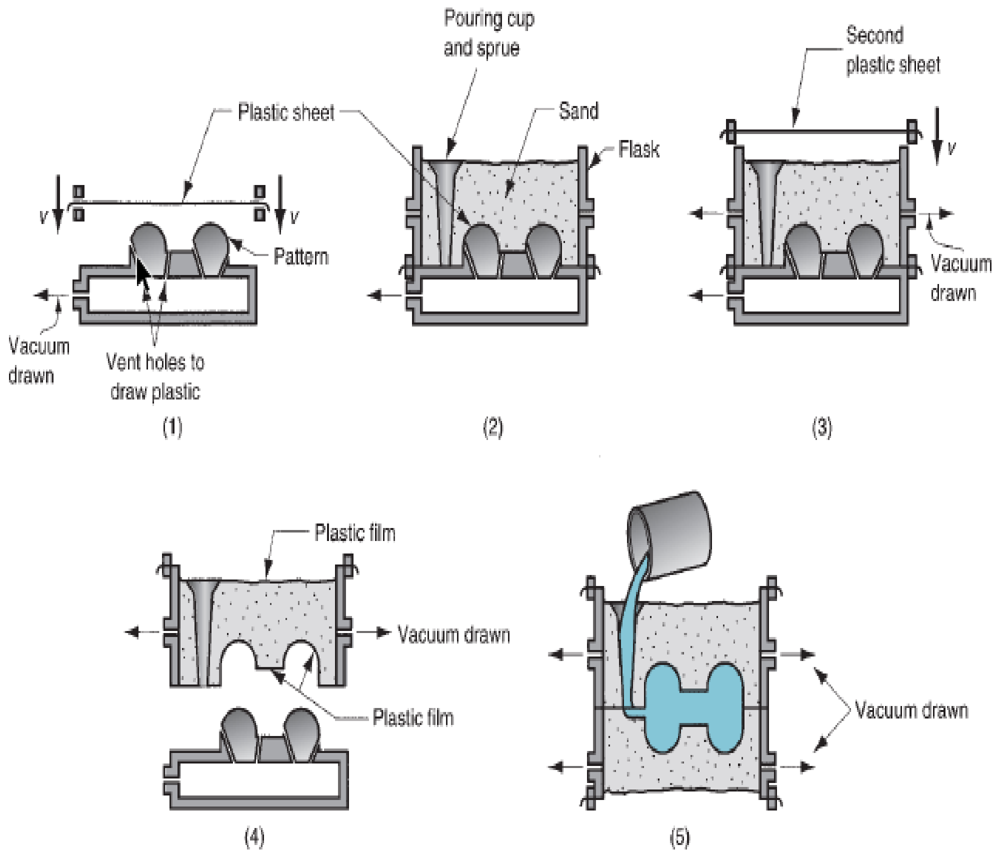
Steps in vacuum molding:

1. Thin sheet of preheated plastic is drawn over a match-plate or cope-and-drag pattern by vacuum—the pattern has small vent holes to facilitate vacuum forming;
2. A specially designed flask is placed over the pattern plate and filled with sand, and a sprue and pouring cup are formed in the sand;
3. Another thin plastic sheet is placed over the flask, and a vacuum is drawn that causes the sand grains to be held together, forming a rigid mold



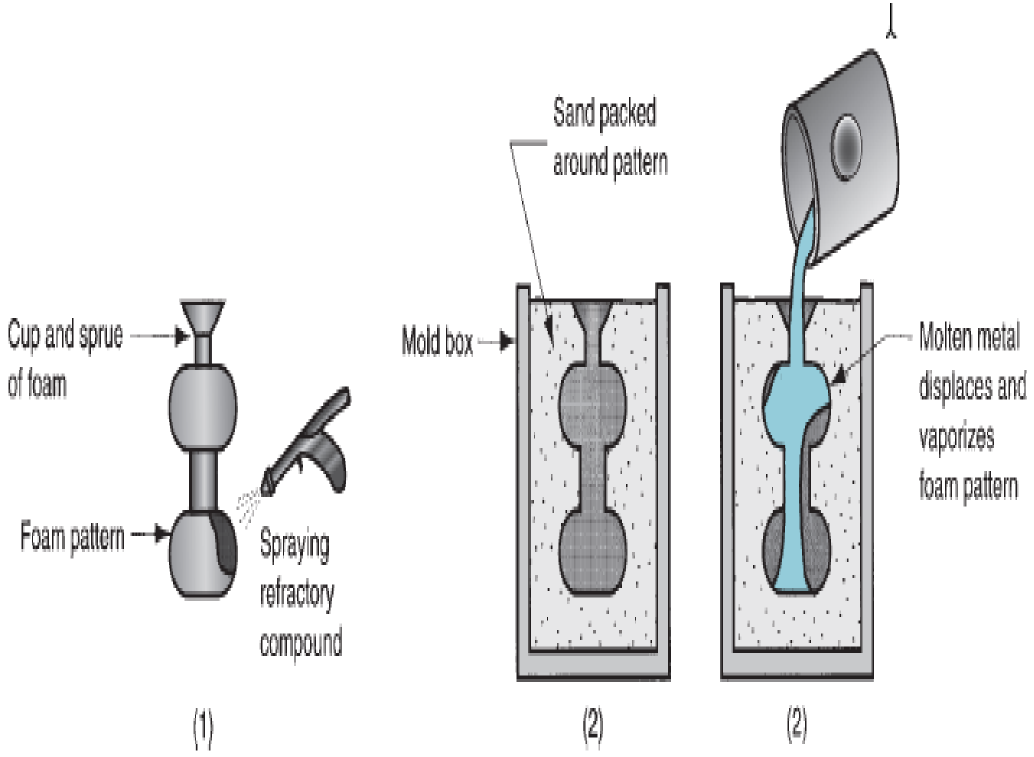
Vacuum Molding

4. the vacuum on the mold pattern is released to permit the pattern to be stripped from the mold;
5. this mold is assembled with its matching half to form the cope and drag, and with vacuum maintained on both halves, pouring is accomplished. The plastic sheet quickly burns away on contacting the molten metal. After solidification, nearly all of the sand can be recovered for reuse.



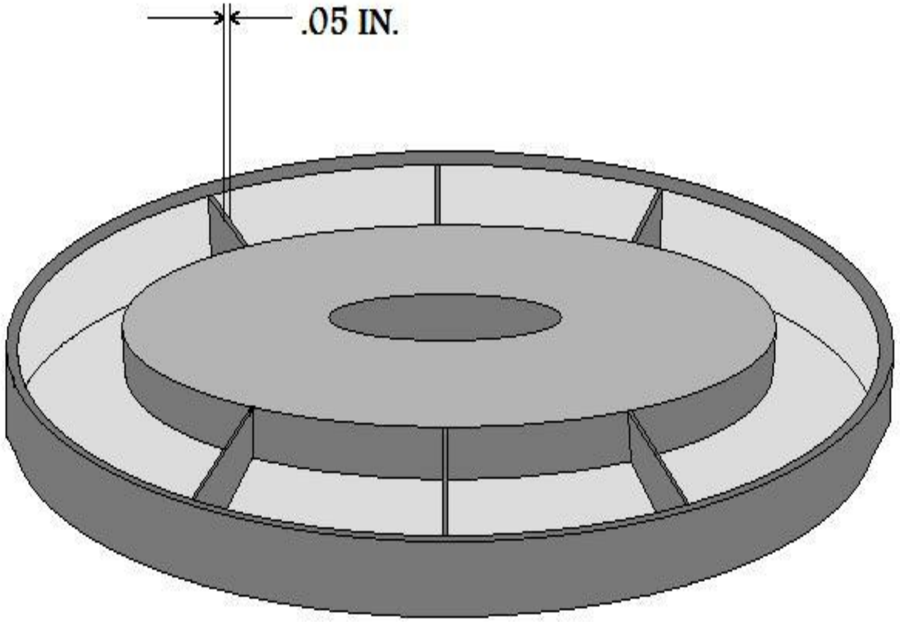
EXPANDED POLYSTYRENE PROCESS

1. pattern of polystyrene is coated with refractory compound
2. Foam pattern is placed in mold box, and sand is compacted around the pattern
3. Molten metal is poured into the portion of the pattern that forms the pouring cup and sprue. As the metal enters the mold, the polystyrene foam is vaporized ahead of the advancing liquid, thus allowing the resulting mold cavity to be filled



PLASTER-MOLD CASTING

1. Evacuating air from the mold cavity before pouring;
2. Aerating the plaster slurry prior to mold making so that the resulting hard plaster contains finely dispersed voids
3. Using a special mold composition and treatment known as the Antioch process



Antioch process

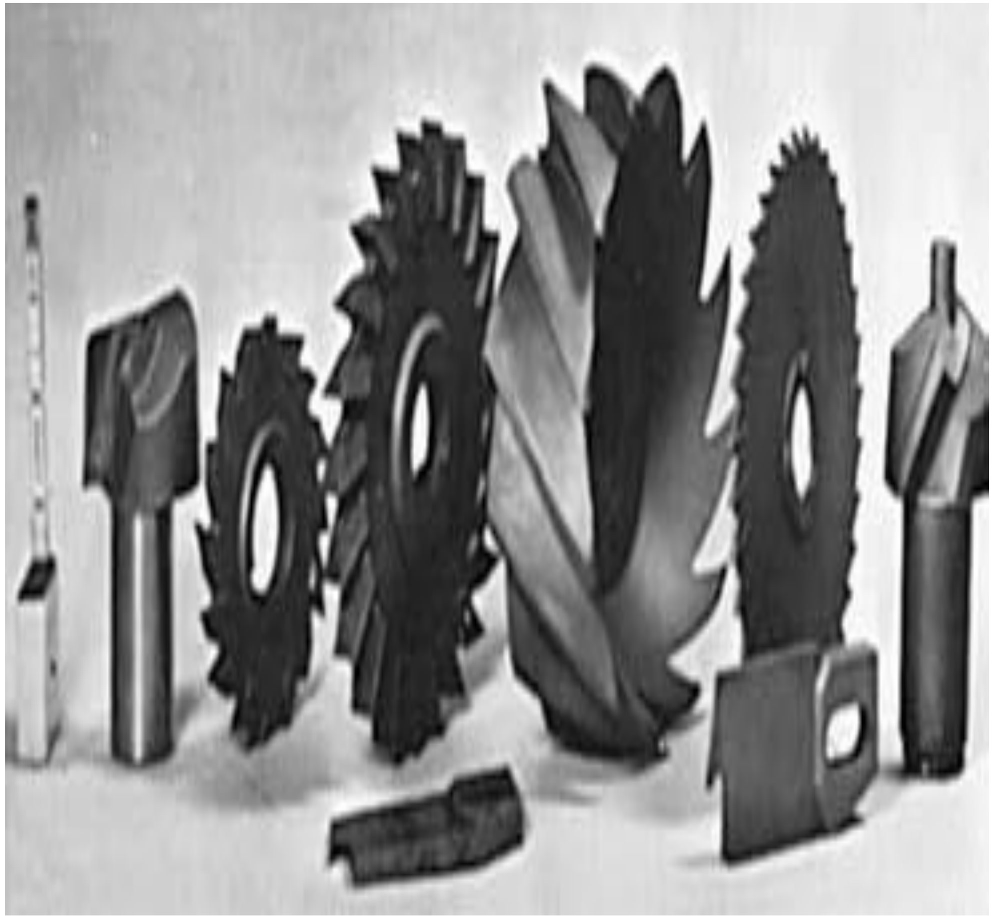
- Antioch process:-This process involves using about 50% sand mixed with the plaster, heating the mold in an autoclave (an oven that uses superheated steam under pressure), and then drying. The resulting mold has considerably greater permeability than a conventional plaster mold

Plaster Casting

- ***Process:*** A slurry of plaster, water, and various additives is poured over a pattern and allowed to set. The pattern is removed, and the mold is baked to remove excess water. After pouring and solidification, the mold is broken and the casting is removed.
- ***Advantages:*** High dimensional accuracy and smooth surface finish; can reproduce thin sections and intricate detail to make net- or near-net-shaped parts.
- ***Limitations:*** Lower-temperature nonferrous metals only; long molding time restricts production volume or requires multiple patterns; mold material is not reusable; maximum size is limited.
- ***Common metals:*** Primarily aluminum and copper.
- ***Size limits:*** As small as 30 g (1 oz.) but usually less than 7 kg (15 lb.).
- ***Thickness limits:*** Section thickness as small as 0.06 cm (0.025 in.).
- ***Typical tolerances:*** 0.01 cm on first 5 cm (0.005 in. on first 2 in.), 0.002 cm per additional cm (0.002 in. per additional in.)
- ***Draft allowance:*** *0.5* –1 degree.
- ***Surface finish:*** 1.3–4 microns (50–125 μin.) rms.

CERAMIC MOLD CASTING

- *Ceramic mold casting* is similar to plaster mold casting, except that the mold is now made from a ceramic material that can withstand the higher melting- temperature metals. Much like the plaster process, ceramic molding can produce thin sections, fine detail, and smooth surfaces, thereby eliminating a considerable amount of finish machining



Ceramic Mold Casting

- ***Process:*** Stable ceramic powders are combined with binders and gelling agents to produce the mold material.
- ***Advantages:*** Intricate detail, close tolerances, and smooth finish.
- ***Limitations:*** Mold material is costly and not reusable.
- ***Common metals:*** Ferrous and high-temperature nonferrous metals are most common; can also be used with alloys of aluminum, copper, magnesium, titanium, and zinc.
- ***Size limits:*** 100 grams to several thousand kilograms (several ounces to several tons).
- ***Thickness limits:*** As thin as 0.13 cm (0.050 in.); no maximum.
- ***Typical tolerances:*** 0.01 cm on the first 2.5 cm (0.005 in. on the first in.), 0.003 cm per each additional cm (0.003 in. per each additional in.).
- ***Draft allowances:*** 1° preferred.
- ***Surface finish:*** 2–4 microns (75–150 μin.) rms.

CONTINUOUS CASTING

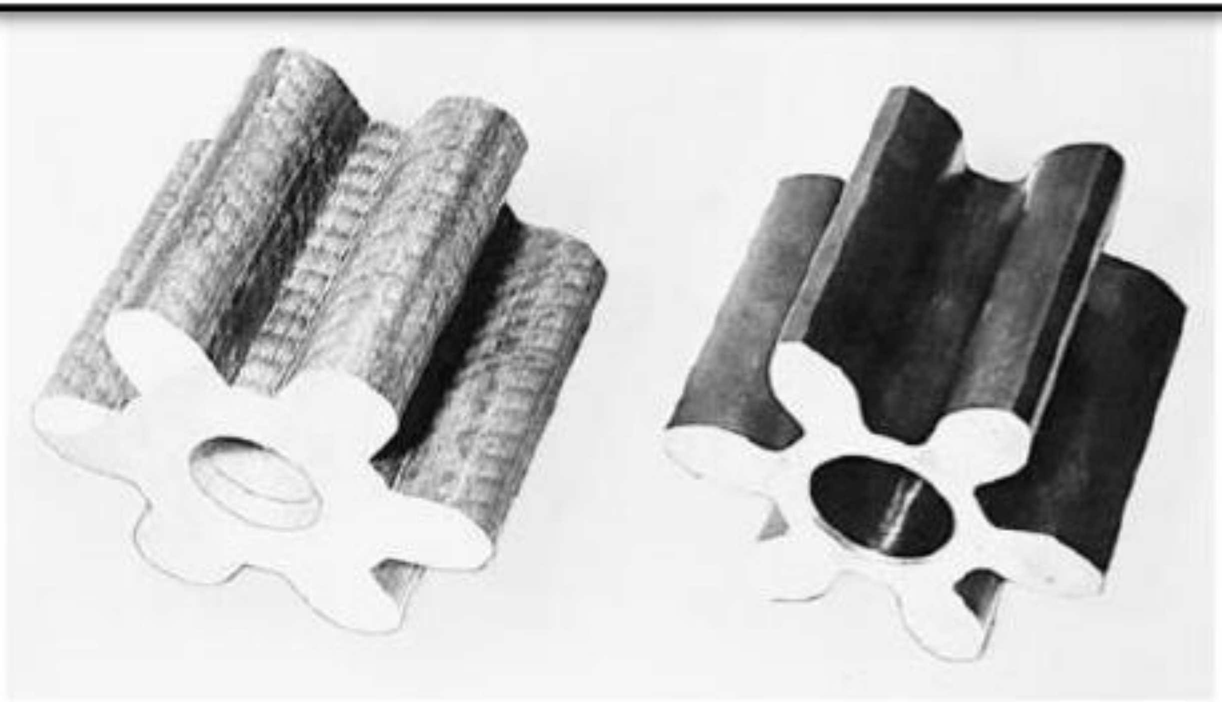


FIGURE 13-13 Gear produced by continuous casting. (Left) As-cast material; (right) after machining. *(Courtesy of ASARCO, Tucson, AZ.)*

CONTINUOUS CASTING

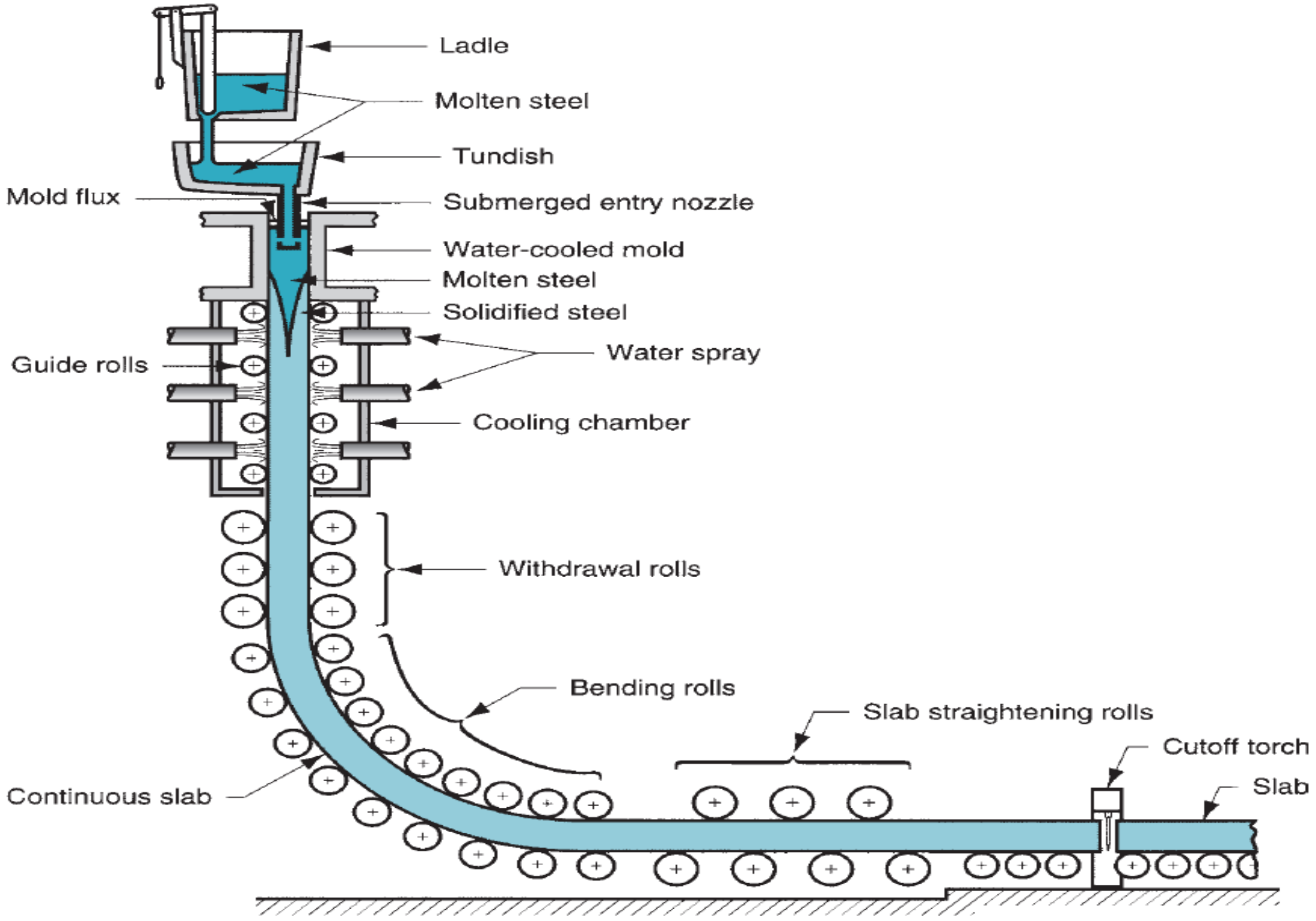
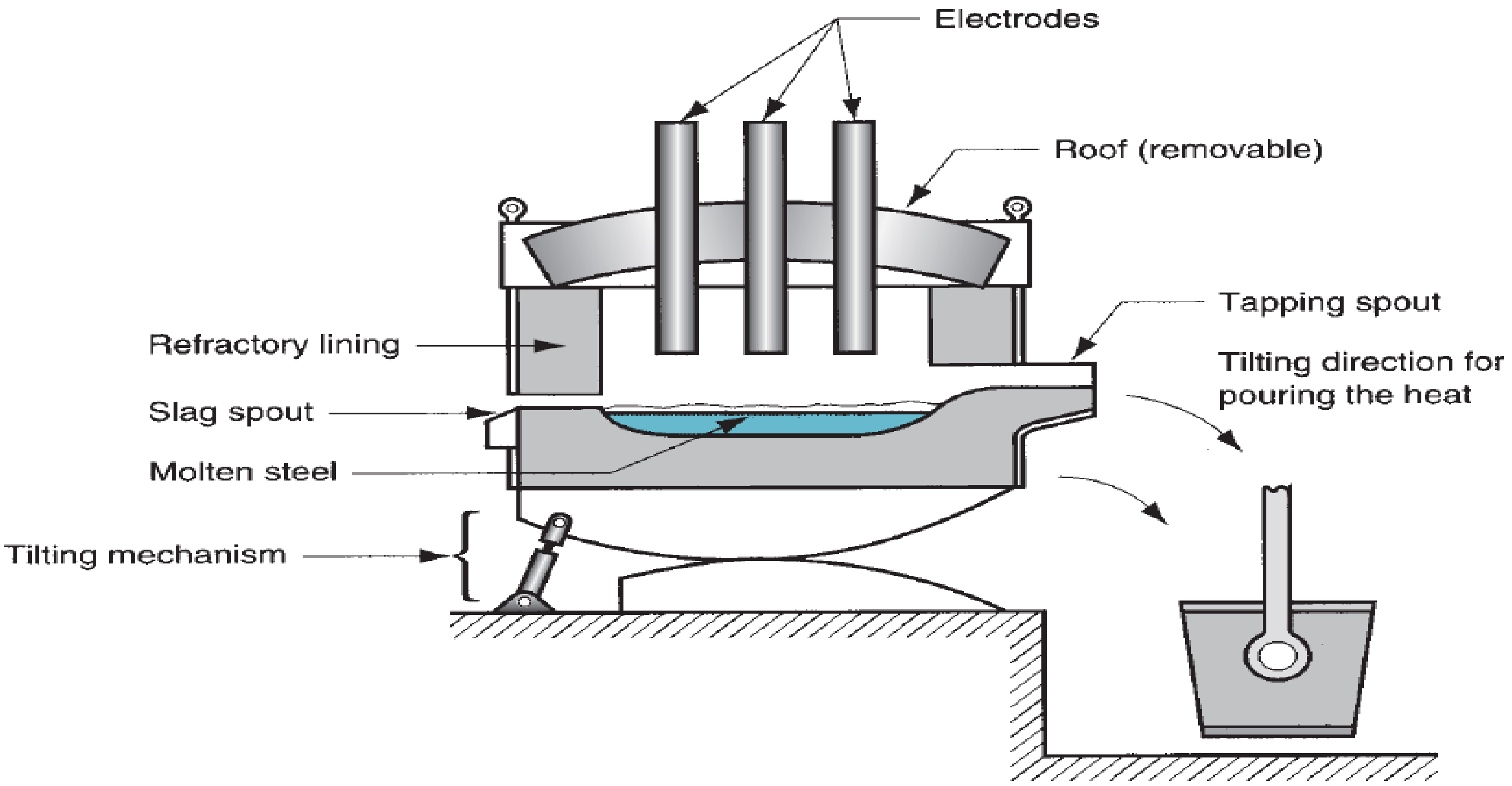


FIGURE 6.11
Continuous casting; steel is poured into tundish and distributed to a water-cooled continuous casting mold; it solidifies as it travels down through the mold. The slab thickness is exaggerated for clarity.

Ingot Casting



EXPENDABLE GRAPHITE MOLDS

- For metals such as titanium, which tend to react with many of the more common mold materials, powdered *graphite* can be combined with additives, such as cement, starch, and water, and compacted around a pattern.
- After “setting,” the pattern is removed and the mold is fired at 1000°C to consolidate the graphite. The casting is poured, and the mold is broken to remove the product

RUBBER-MOLD CASTING

- Artificial elastomers can also be compounded in liquid form and poured over a pattern to produce a semi rigid mold.
- These molds are sufficiently flexible to permit stripping from an intricate shape or patterns with reverse-taper surfaces.
- Unfortunately, rubber molds are generally limited to small castings and low-melting-point materials.
- The wax patterns used in investment casting are often made by rubber-mold casting, as are small quantities of finished parts made from plastics or metals that can be poured at temperatures below 250°C (500°F).

SQUEEZE CASTING AND SEMISOLID CASTING

- Squeeze casting and semisolid casting are methods that enable the production of high quality, near-net-shape, thin-walled parts with good surface finish and dimensional precision as well as properties that approach those of forgings.
- Both processes can be viewed as derivatives of conventional high-pressure die casting, since they employ tool steel dies and apply high pressure during solidification.
- While the majority of applications involve alloys of aluminum, each of the processes has been successfully applied to magnesium, zinc, copper, and a limited number of ferrous alloys.

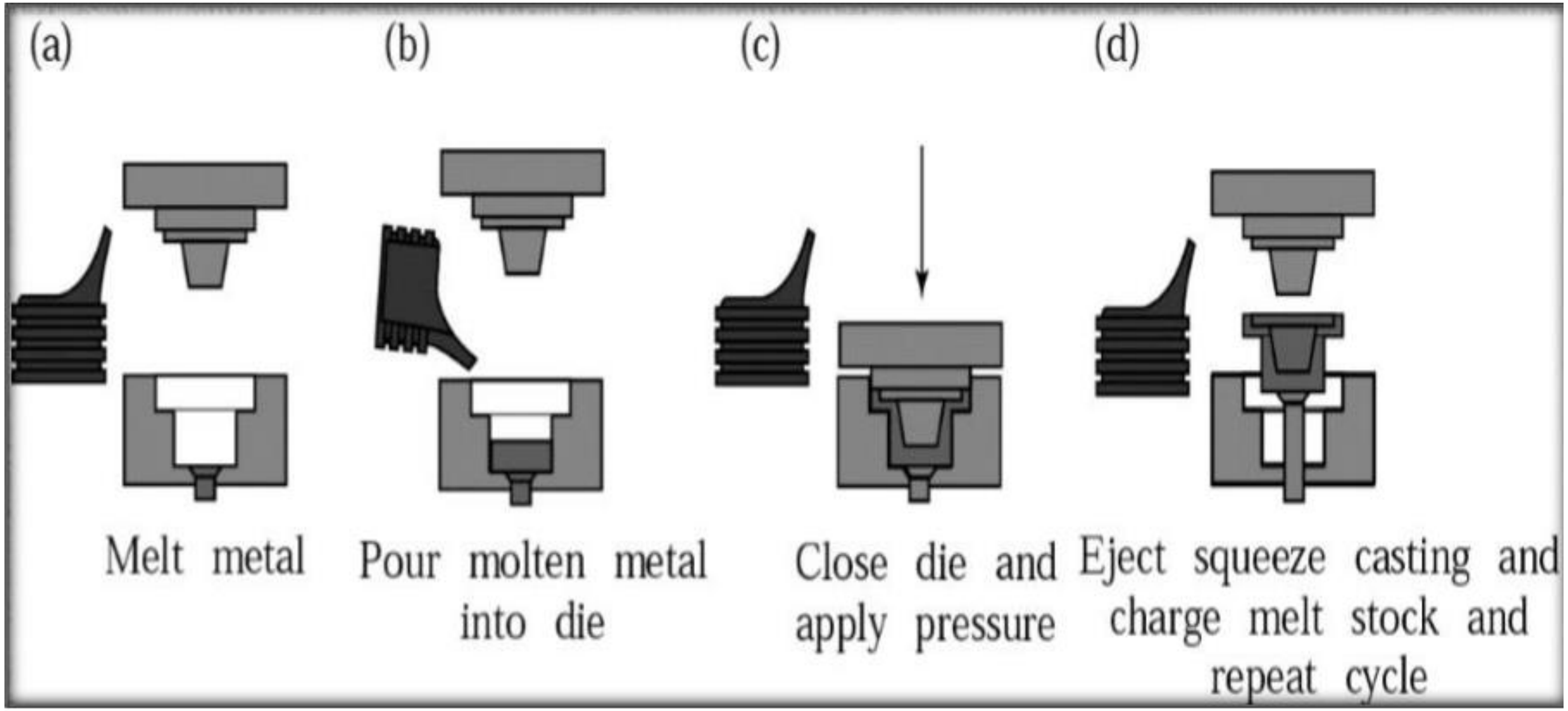
<u>Squeeze Casting</u>

- In the *squeeze casting* process, molten metal is introduced into the die cavity of a metal mold, using large gate areas and slow metal velocities to avoid turbulence.
- When the cavity has filled, high pressure (20 to 175 MPa) is then applied and maintained during the subsequent solidification.
- Parts must be designed to directionally solidify toward the gates, and the gates must be sufficiently large that they freeze after solidification in the cavity, thereby allowing the pressurized runner to feed additional metal to compensate for shrinkage.

Squeeze Casting

- Intricate shapes can be produced at lower pressures than would normally be required for hot or cold forging.
- Both retractable and disposable cores can be used to create holes and internal passages.
- Gas and shrinkage porosity are substantially reduced, and mechanical properties are enhanced.
- While the squeeze casting process is most commonly applied to aluminum and magnesium castings, it has also been adapted to the production of metal-matrix composites where the pressurized metal is forced around or through foamed or fiber reinforcements that have been positioned in the mold.

SQUEEZE CASTING



SEMISOLID CASTING

- While the majority of applications involve alloys of aluminum ,each of the processes has been successfully applied to magnesium ,zinc, copper, and a limited number of ferrous alloys

Advantages of Semi-Solid metal casting include the following :-

1. Complex part geometries,
2. Thin walls in parts
3. Close tolerances
4. Zero or low porosity

SEMISOLID CASTING

- For most alloy compositions, there is a range of temperatures where liquid and
- solid coexist, and several techniques have been developed to produce shapes from this *Semisolid* material

SEMISOLID CASTING
Thixocasting

- The prefix in thixocasting is derived from the word thixotropy, which refers to the decrease in viscosity of some fluid-like materials when agitated.
- the starting work material is a precast billet that has a non-dendritic microstructure; this is heated into the semisolid temperature range and injected into a mold cavity using die casting equipment
- When applied to magnesium, the term is thixomolding, which utilizes equipment similar to an injection-molding machine

SEMISOLID CASTING
Rheocasting

- The prefix in rheocasting comes from rheology, the science that relates deformation and flow of materials
- In *rheocasting,* a semisolid slurry is injected into the mold cavity by a die casting machine, very much like conventional die casting.
- In the *rheocasting* process, molten metal is cooled to the semisolid state with constant stirring. The stirring or shearing action breaks up the dendrites, producing a slurry of rounded particles of solid in a liquid melt.
- This slurry, with about a 30% solid content, can be readily shaped by high-pressure injection into metal dies. Becausethe slurry contains no superheat and is already partially solidified, it freezes quickly

SEMISOLID CASTING

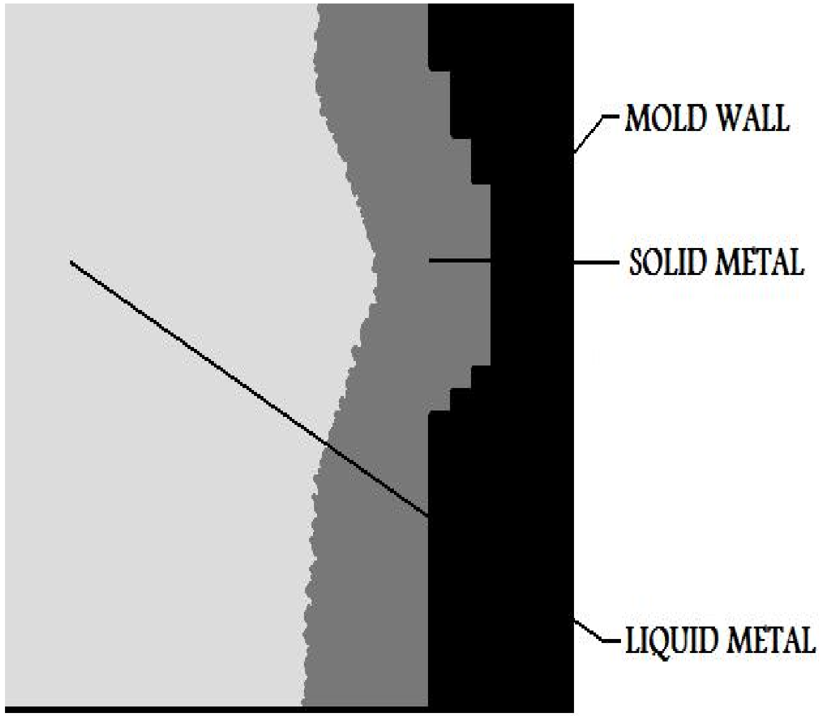
- In all of the semisolid casting processes, the absence of turbulent flow during the casting operation minimizes gas pickup and entrapment. Because the material is already partially solid, the lower injection temperatures and reduced solidification time act to extend tool life.
- The prior solidification coupled with further solidification under pressure results in a significant reduction in solidification shrinkage and related porosity.
- The minimization of porosity enables the use of high-temperature heat treatments, such as the T6 solution treatment and artificial aging of aluminum, to further enhance strength.
- Since the thixocasting process does not use molten metal, both wrought and cast alloys have been successfully shaped.
- Walls have been produced with thickness as low as 0.2 mm .

SQUEEZE CASTING AND SEMISOLID CASTING

- Squeeze casting and semisolid casting are methods that enable the production of high quality, near-net-shape, thin-walled parts with good surface finish and dimensional precision as well as properties that approach those of forgings
- Both processes can be viewed as derivatives of conventional high-pressure die casting, since they employ tool steel dies and apply high pressure during solidification

Slush Casting

- Slush casting is a permanent-mold process in which a hollow casting is formed by inverting the mold after partial freezing at the surface to drain out the liquid metal in the center .

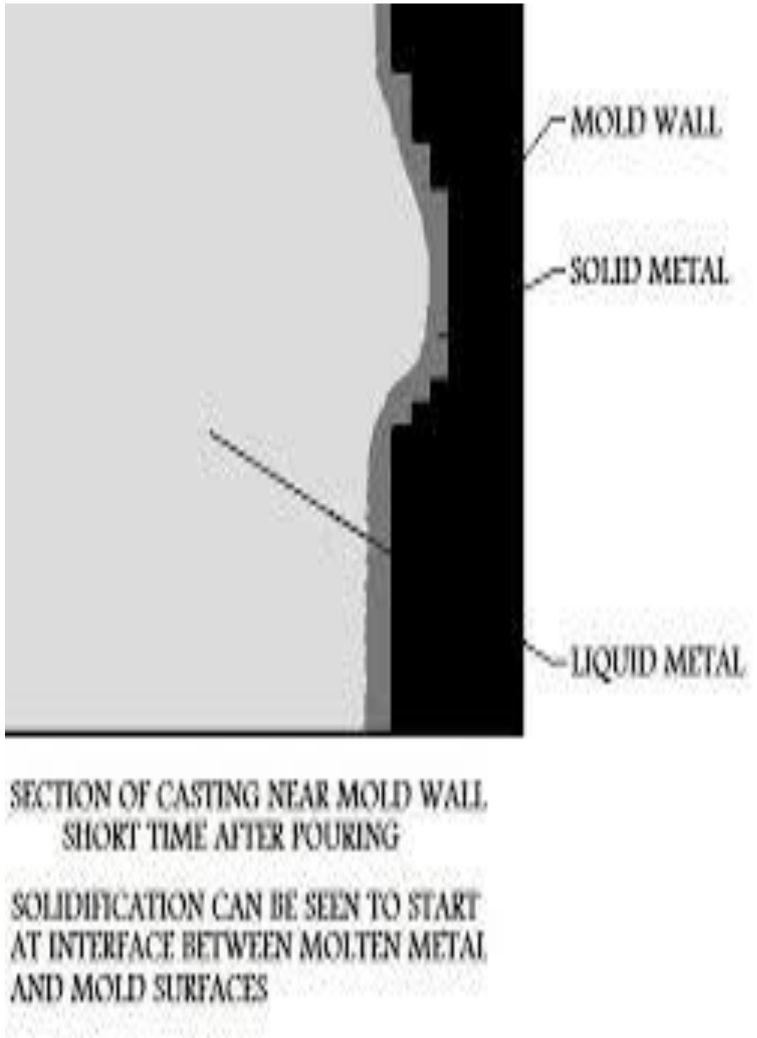


SECTION OF CASTING NEAR MOLD WALL
LONGER TIME AFTER POURING

SOLIDIFICATION PROGRESSES FROM MOLD-CASTING INTERFACE TOWARRDS INNER REGIONS OF THE MATERIAL THICKNESS OF THIS SOLID SECTION INCREASES WITH TIME

Slush Casting

- The process is limited to castings made of lower melting point metals such as lead, tin, and zinc alloys.
- Typical products are lamp bases (pedestals), candle sticks, and small statues.

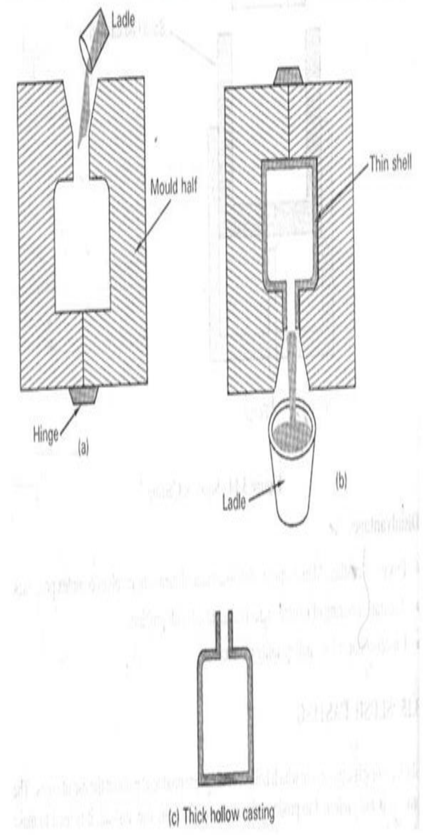


Slush Casting

The thickness of the cast wall depends on

1. The time interval between filling and Inverting of the mold
2. The Chemical and Physical properties of the alloy,
3. The Mold temperature.

- The outer surface of the product is highly controlled by the finishing of the die cavity, but the inner surface is rough.



Low-Pressure Casting

- In the basic permanent-mold casting process and in slush casting, the flow of metal into the mold cavity is caused by gravity.
- In low-pressure casting, the liquid metal is forced into the cavity under low pressure—approximately 0.1 MPa(14.5lb/in^2)—from beneath so that the flow is upward, as illustrated in figure aside

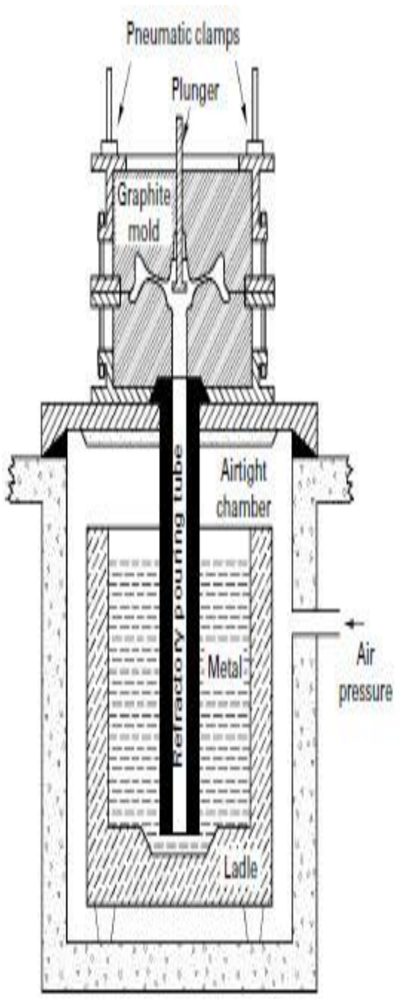
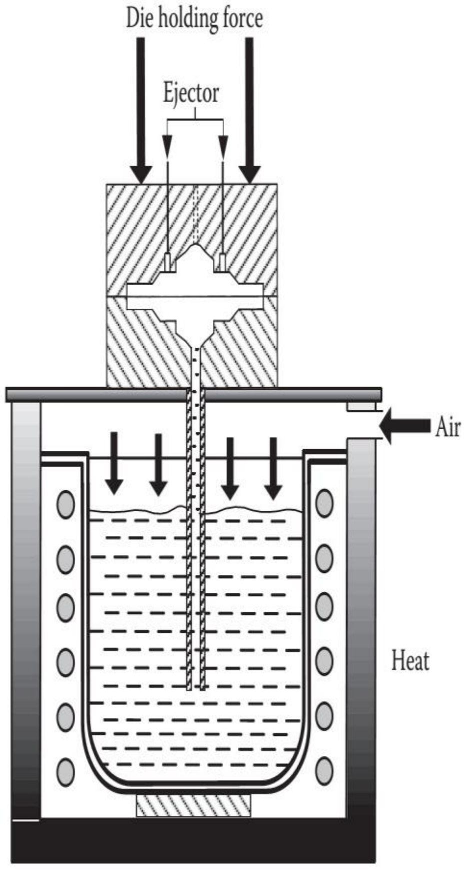


FIGURE 13-2 Schematic of the low-pressure permanent-mold process. *(Courtesy of Amsted Industries, Chicago, IL.)*

Low-Pressure Casting

- In low pressure casting, the mold is placed upside-down right above the melting or holding furnace, and metal is fed under air pressure through the bottom gate into the mold cavity, This facilitates smooth filling of the die, and solidification is directed from the top downward,
- Air pressure is released as soon as the cavity is filled with solid metal, ensuring minimal material losses. The holding pressure of the die halves is larger than in gravity die casting to resist the forces developed by the liquid metal pressure in the cavity.
- The process is widely applied for aluminum alloys.



Low-Pressure Casting

- The advantage of this approach over traditional pouring is that

1. Clean molten metal from the center of the ladle is introduced into the mold, rather than metal that has been exposed to air.
2. Gas porosity and oxidation defects are thereby minimized,
3. Mechanical properties are improved.

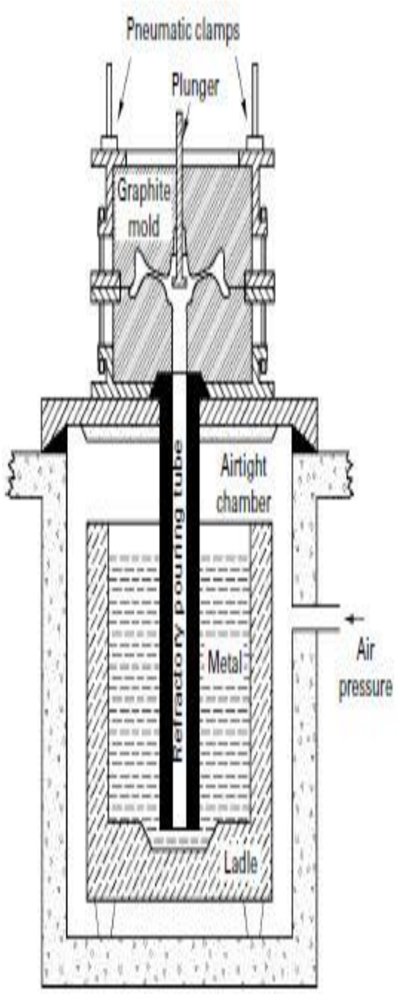
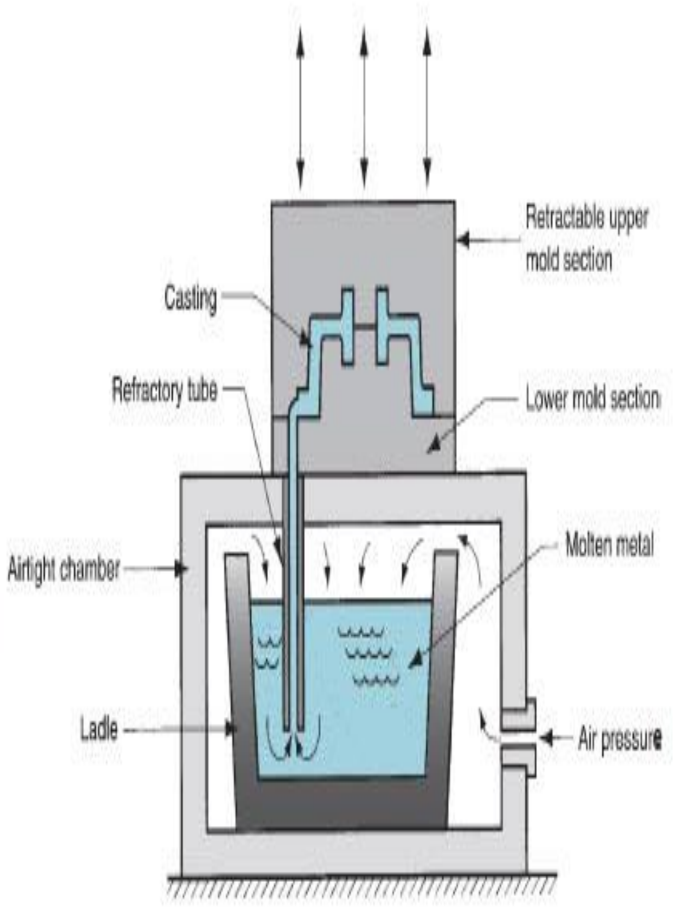


FIGURE 13-2 Schematic of the low-pressure permanent-mold process. *(Courtesy of Amsted Industries, Chicago, IL.)*

Vacuum Permanent-Mold Casting

- Not to be confused with vacuum molding ,this process is a variation of low-pressure casting in which a vacuum is used to draw the molten metal in to the mold cavity.
- The general configuration of the vacuum permanent mold casting process is similar to the low-pressure casting operation .



Vacuum Permanent-Mold Casting

- The difference is that reduced air pressure from the vacuum in the mold is used to draw the liquid metal into the cavity, rather than forcing it by positive air pressure from below.
- There are several benefits of the vacuum technique relative to low-pressure casting: air porosity and related defects are reduced, and greater strength is given to the cast product.
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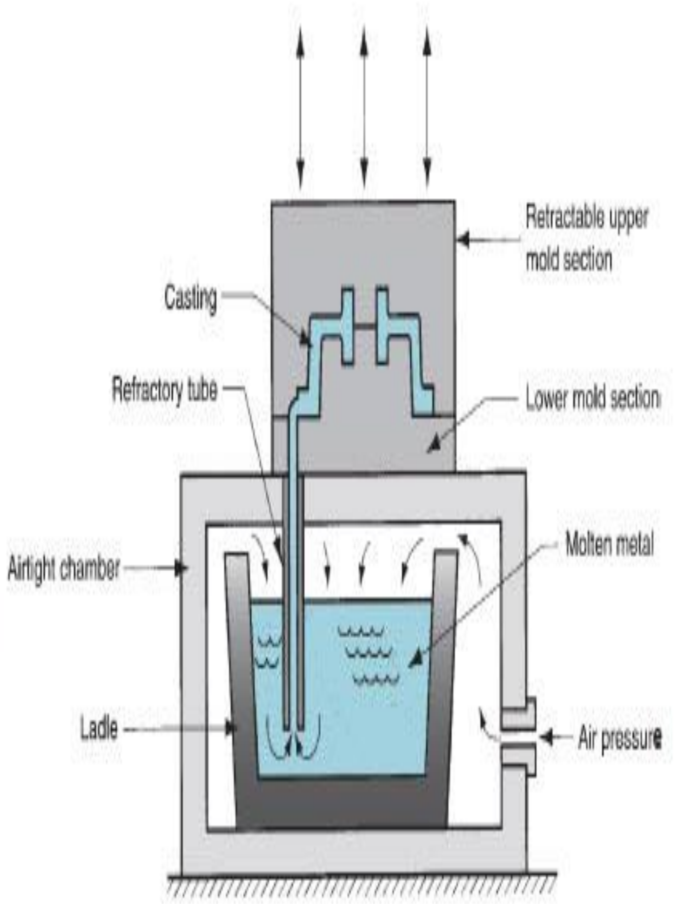

Vacuum Permanent-Mold Casting

- This is a variation of low pressure casting, where vacuum is used to draw the molten metal into
- the mold cavity instead of forcing it under low pressure.
- Vacuum reduces the pressure in the cavity to about two thirds of the atmospheric pressure. This leads to elimination of the air porosity, and imparts greater strength to the casting.
- It is mostly applicable for thin-walled, complex shapes. Carbon steels and stainless steels weighing up to 70 kg have been vacuum cast.