



Metal Casting Processes

Manufacturing Processes-1, IE252

Dr M.Eissa



METAL CASTING PROCESSES

- Sand Casting
- Other Expendable Mold Casting Processes
- Permanent Mold Casting Processes
- Foundry Practice
- Casting Quality
- Metals for Casting
- Product Design Considerations



Two Categories of Casting Processes

Expendable mold processes - mold is sacrificed to remove part

- Advantage: more complex shapes possible
- Disadvantage: production rates often limited by time to make mold rather than casting itself

Permanent mold processes - mold is made of metal and can be used to make many castings

- Advantage: higher production rates
- Disadvantage: geometries limited by need to open mold



Overview of Sand Casting

Most widely used casting process, accounting for a significant majority of total tonnage cast

Nearly all alloys can be sand casted, including metals with high melting temperatures, such as steel, nickel, and titanium

Castings range in size from small to very large
Production quantities from one to millions

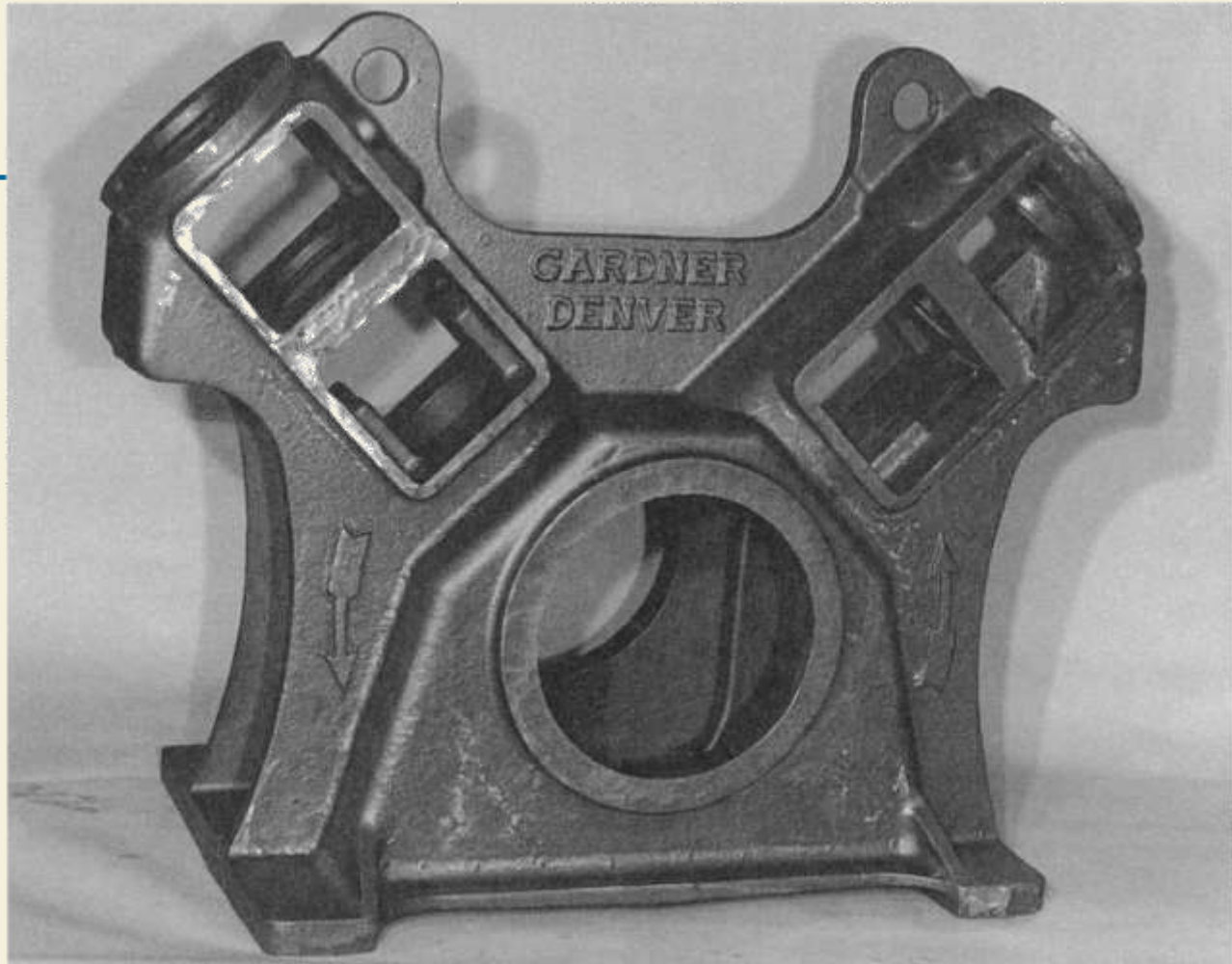


Figure 11.1 A large sand casting weighing over 680 kg (1500 lb) for an air compressor frame (photo courtesy of Elkhart Foundry).



Steps in Sand Casting

1. Pour the molten metal into sand mold
2. Allow time for metal to solidify
3. Break up the mold to remove casting
4. Clean and inspect casting
 - Separate gating and riser system
5. Heat treatment of casting is sometimes required to improve metallurgical properties



Steps in Sand Casting in detail

1. Place pattern on molding board.
2. Place drag parting surface down on molding board.
3. Riddle sand over pattern until covered.
4. Press sand around pattern with fingers.
5. Completely fill drag with sand.
6. Use a ram to pack sand.
7. Remove excess sand with strike rod.
8. Make vent holes for gases to escape.
9. Place bottom board on drag.
10. Turn over drag and remove molding board.
11. Smooth molding sand.
12. Add fine coat of parting sand.
13. Place the cope on the drag.
14. Add sprue pin ~ 1" to side of pattern.
15. Fill, ram, & vent cope as done.
16. Withdraw sprue pin.
17. Create a funnel opening.
18. Separate cope from drag.
19. Moisten drag mold edges with swab.
20. Use draw spike to loosen pattern.
21. Remove the pattern.
22. Cut gate from sprue to pattern cavity.
23. Cut riser in cope to channel hot metal.
24. Spray, swab, or dust the mold surfaces with coating material.
25. Re-assemble cope and drag to prepare for pouring.
26. Weight cope to prevent seepage at parting line.
27. Pour the metal.
28. Allow to cool.
29. Separate and clean casting.
30. Reclaim the sand & clean the flask.

Check this out: <http://foundry101.com/1.htm>



Making the Sand Mold

The cavity in the sand mold is formed by packing sand around a pattern, then separating the mold into two halves and removing the pattern

The mold must also contain gating and riser system

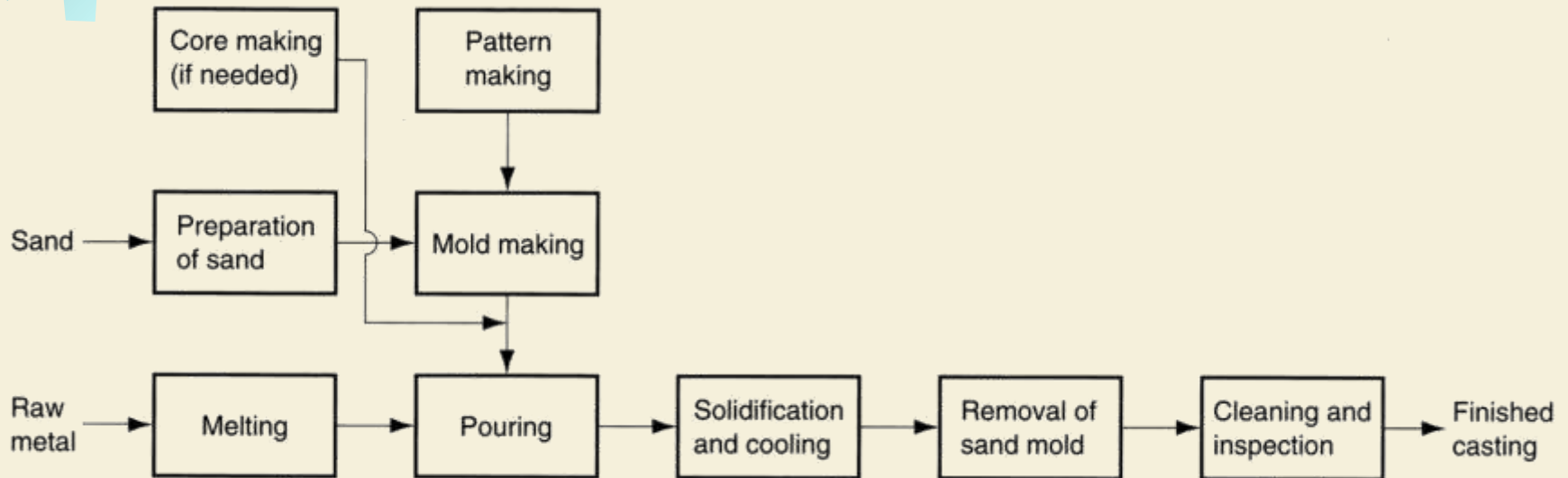
If casting is to have internal surfaces, a core must be included in mold

A new sand mold must be made for each part produced

Sand Casting Production Sequence

Figure 11.2 Steps in the production sequence in sand casting.

The steps include not only the casting operation but also *pattern-making* and *mold-making*.





The Pattern

A full-sized model of the part, slightly enlarged to account for shrinkage and machining allowances in the casting

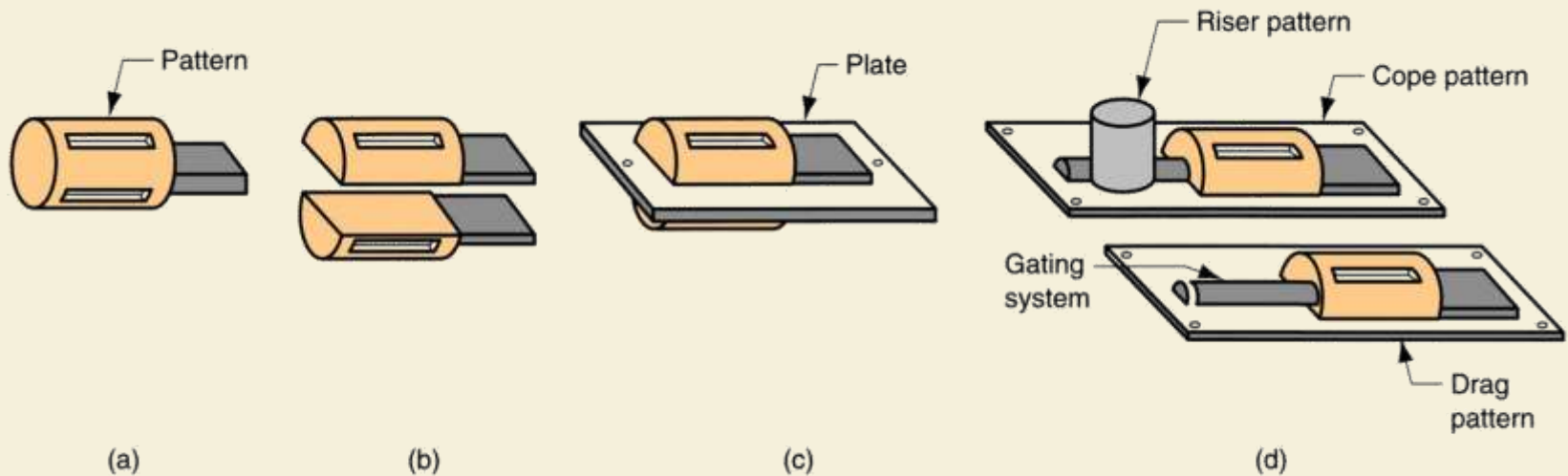
Pattern materials:

- **Wood** - common material because it is easy to work, but it warps
- **Metal** - more expensive to make, but lasts much longer
- **Plastic** - compromise between wood and metal

Types of Patterns

Figure 11.3 Types of patterns used in sand casting:

- (a) solid pattern
- (b) split pattern
- (c) match-plate pattern
- (d) cope and drag pattern



Core

Full-scale model of interior surfaces of part

It is inserted into the mold cavity prior to pouring

The molten metal flows and solidifies between the mold cavity and the core to form the casting's external and internal surfaces. May require supports to hold it in position in the mold cavity during pouring, called *chaplets*

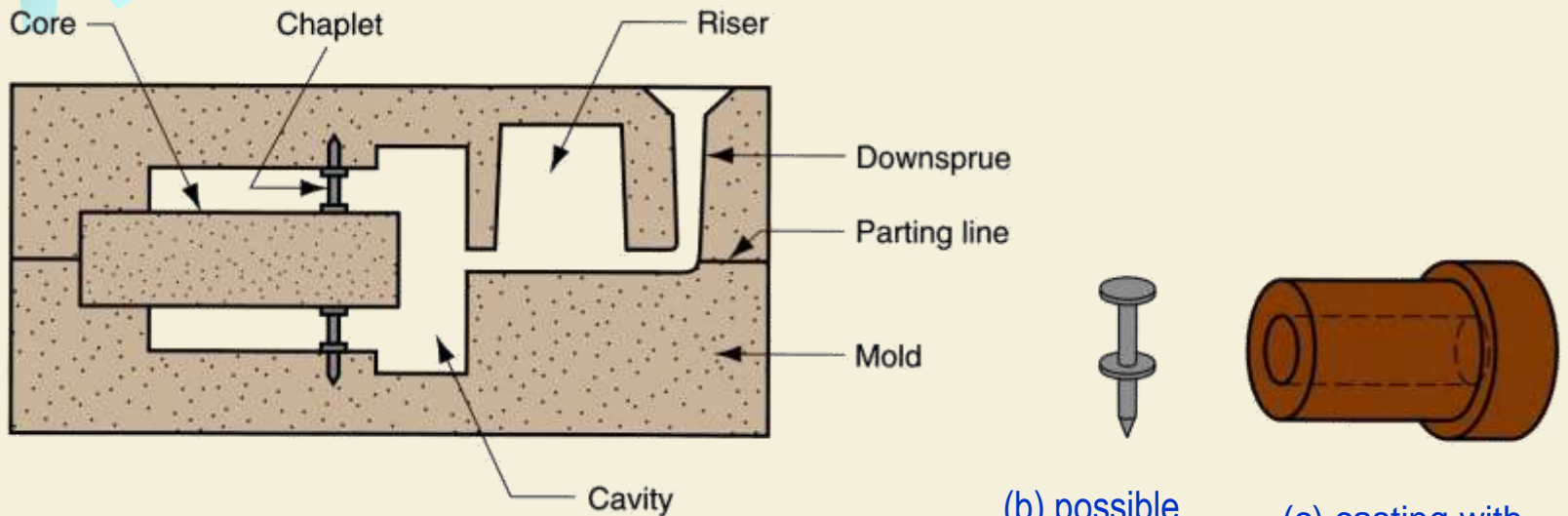


Figure 11.4 (a) Core held in place in the mold cavity by chaplets,

(b) possible chaplet design,

(c) casting with internal cavity.



Desirable Mold Properties

Strength - to maintain shape and resist erosion

Permeability - to allow hot air and gases to pass through voids in sand

Thermal stability - to resist cracking on contact with molten metal

Collapsibility - ability to give way and allow casting to shrink without cracking the casting

Reusability - can sand from broken mold be reused to make other molds?

Erosion: to eat into or away by slow destruction of substance

Permeability: capable of being penetrable



Foundry Sands

Silica (SiO_2) or silica mixed with other minerals

Good refractory properties - capacity to endure high temperatures

Small grain size yields better surface finish on the cast part

Large grain size is more permeable, allowing gases to escape during pouring

Irregular grain shapes strengthen molds due to interlocking, compared to round grains

Disadvantage: interlocking tends to reduce permeability



Binders Used with Foundry Sands

Sand is held together by a mixture of water and bonding clay

- Typical mix: 90% sand, 3% water, and 7% clay

Other bonding agents also used in sand molds:

- **Organic resins** (eg , phenolic resins)
- **Inorganic binders** (eg , sodium silicate and phosphate)

Additives are sometimes combined with the mixture to increase strength and/or permeability

Phenol = a corrosive poisonous crystalline acidic compound C_6H_5OH present in the tars of coal and wood that in dilute solution is used as a disinfectant



Types of Sand Mold

Green-sand molds - mixture of sand, clay, and water;

- “**Green**” means mold contains moisture at time of pouring

Dry-sand mold - organic binders rather than clay

- And mold is baked to improve strength

Skin-dried mold - drying mold cavity surface of a green-sand mold to a depth of 10 to 25 mm, using torches or heating lamps



Buoyancy in Sand Casting Operation

During pouring, buoyancy of the molten metal tends to displace the core, which can cause casting to be defective

Force tending to lift core = weight of displaced liquid less the weight of core itself

$$F_b = W_m - W_c$$

where F_b = buoyancy force;

W_m = weight of molten metal displaced; and

W_c = weight of core



Other Expendable Mold Processes

Students' presentations

- Shell Molding
- Vacuum Molding
- Expanded Polystyrene Process
- Investment Casting
- Plaster Mold and Ceramic Mold Casting

Shell Molding

Casting process in which the mold is a thin shell of sand held together by thermosetting resin binder

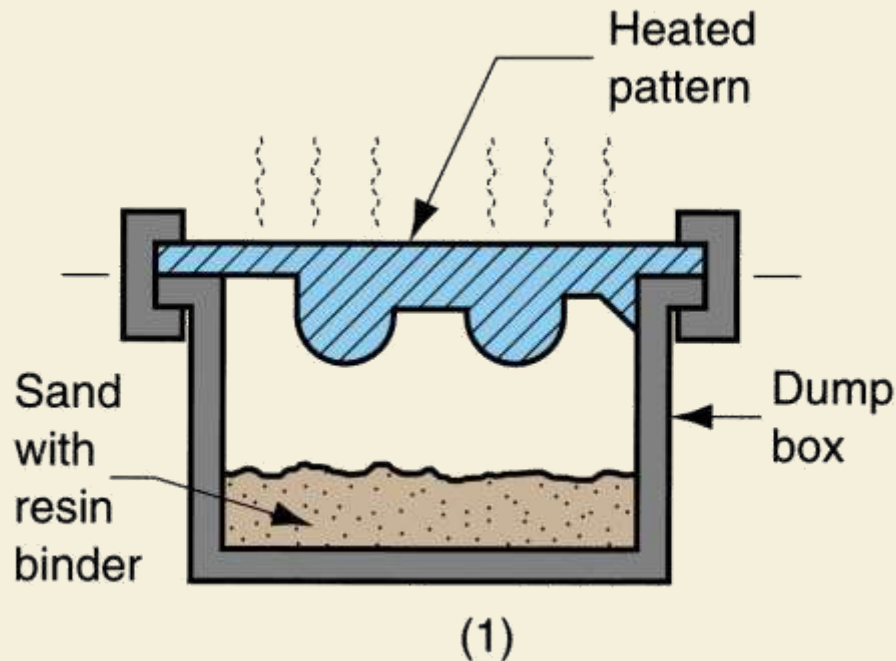
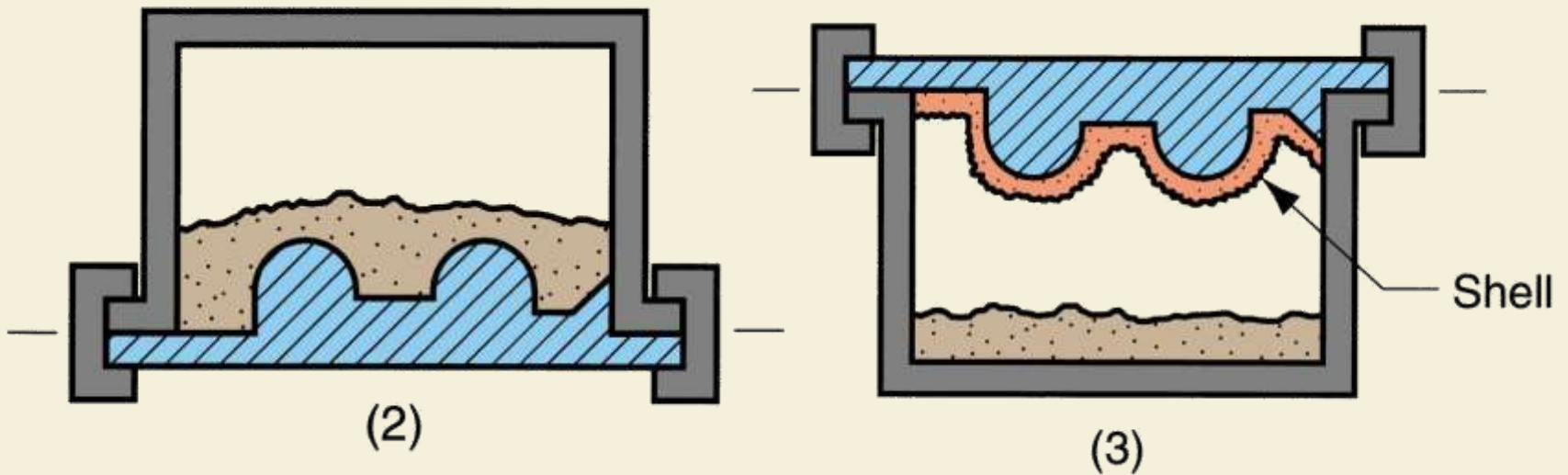


Figure 11.5 Steps in shell-molding: (1) a match-plate or cope-and-drag metal pattern is heated and placed over a box containing sand mixed with thermosetting resin.

Shell Molding

Figure 11.5 Steps in shell-molding: (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;



Shell Molding

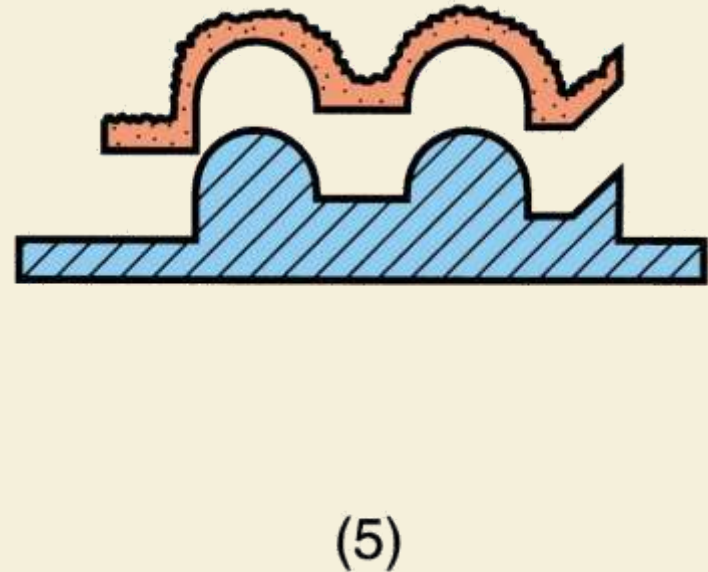
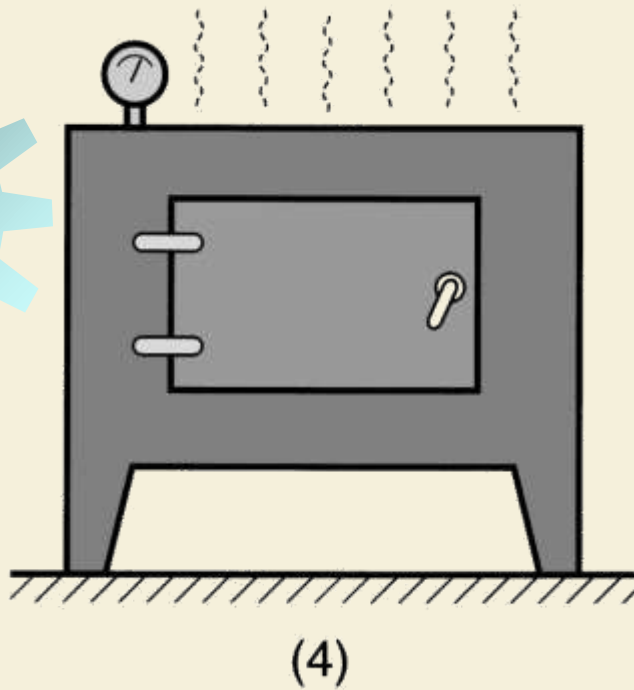


Figure 11.5 Steps in shell-molding: (4) sand shell is heated in oven for several minutes to complete curing; (5) shell mold is stripped from the pattern;

Shell Molding

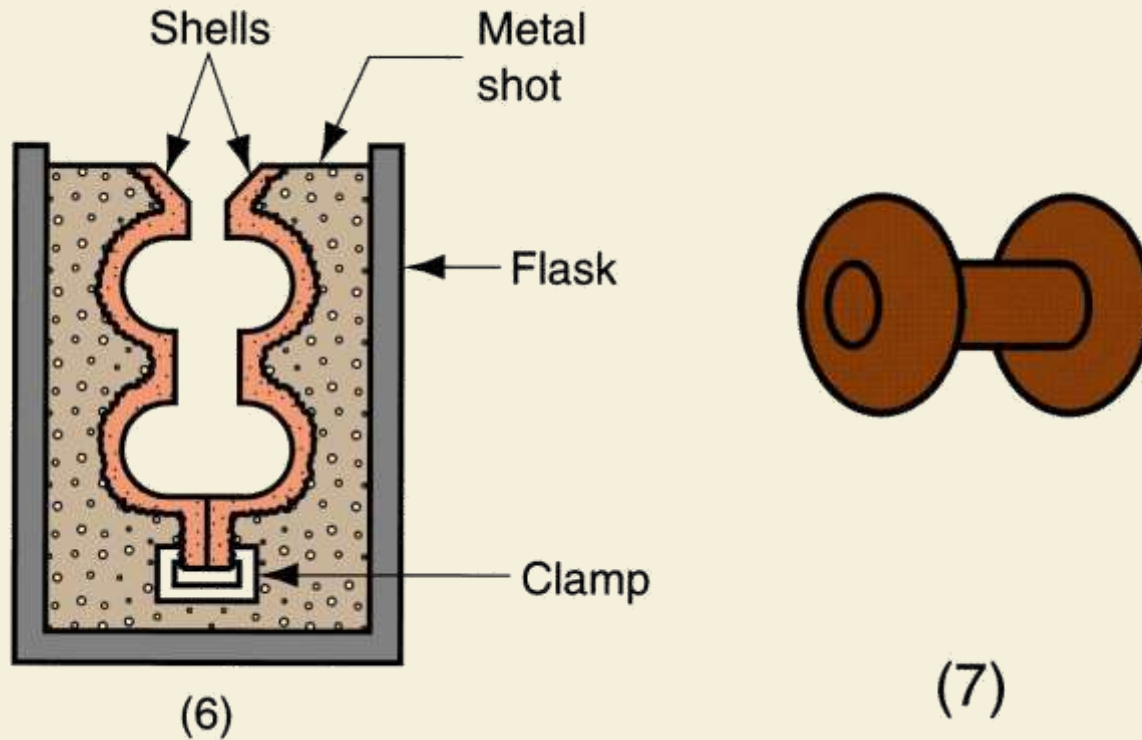


Figure 11.5 Steps in shell-molding: (6) two halves of the shell mold are assembled, supported by sand or metal shot in a box, and pouring is accomplished; (7) the finished casting with sprue removed.



Advantages and Disadvantages

Advantages of shell molding:

- Smoother cavity surface permits easier flow of molten metal and better surface finish
- Good dimensional accuracy - machining often not required
- Mold collapsibility minimizes cracks in casting
- Can be mechanized for mass production

Disadvantages:

- More expensive metal pattern
- Difficult to justify for small quantities



Vacuum Molding

Uses sand mold held together by vacuum pressure rather than by a chemical binder

The term "vacuum" refers to mold making rather than casting operation itself

Developed in Japan around 1970



Advantages and Disadvantages

Advantages of vacuum molding:

- Easy recovery of the sand, since no binders
- Sand does not require mechanical reconditioning done when binders are used
- Since no water is mixed with sand, moisture-related defects are absent

Disadvantages:

- Slow process
- Not readily adaptable to mechanization



Expanded Polystyrene Process

Uses a mold of sand packed around a polystyrene foam pattern which vaporizes when molten metal is poured into mold

Other names: lost-foam process, lost pattern process, evaporative-foam process, and full-mold process

Polystyrene foam pattern includes sprue, risers, gating system, and internal cores (if needed)

Mold does not have to be opened into cope and drag sections

Expanded Polystyrene Process

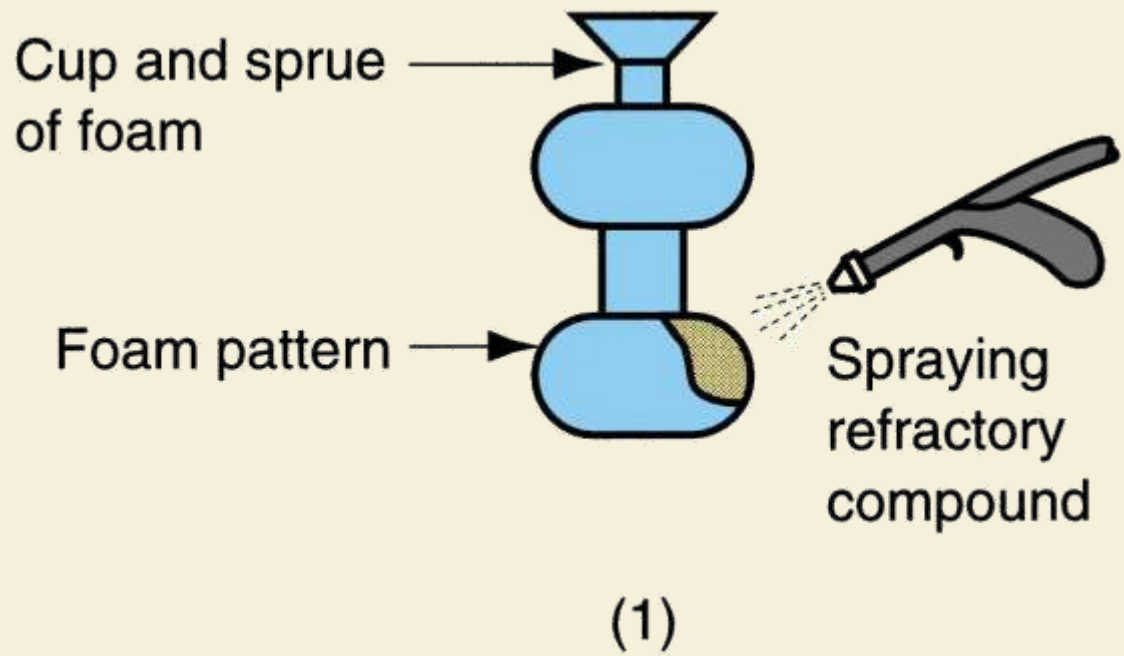


Figure 11.7 Expanded polystyrene casting process: (1) pattern of polystyrene is coated with refractory compound;

Expanded Polystyrene Process

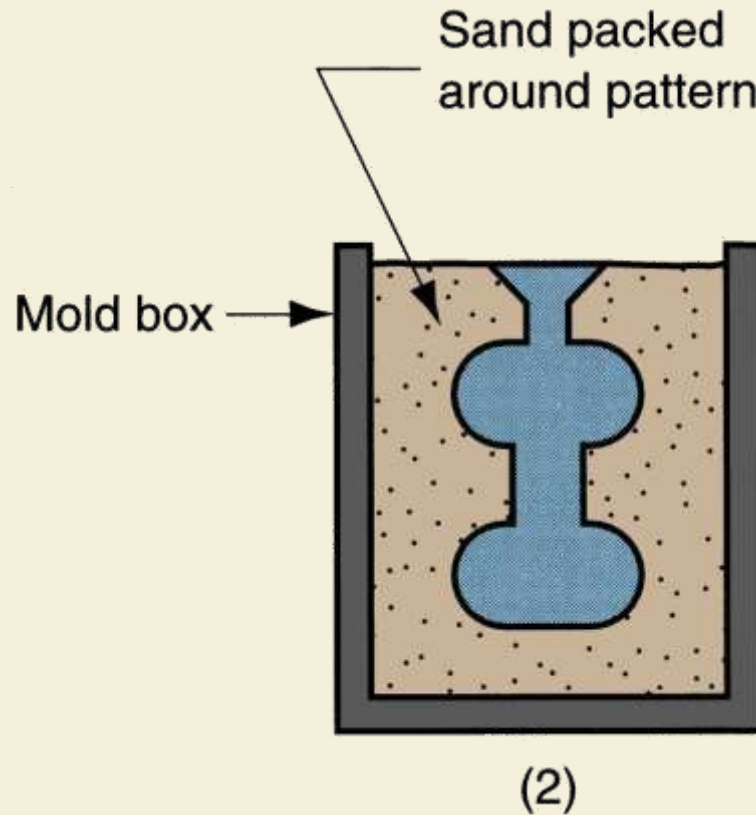


Figure 11.7 Expanded polystyrene casting process: (2) foam pattern is placed in mold box, and sand is compacted around the pattern;

Expanded Polystyrene Process

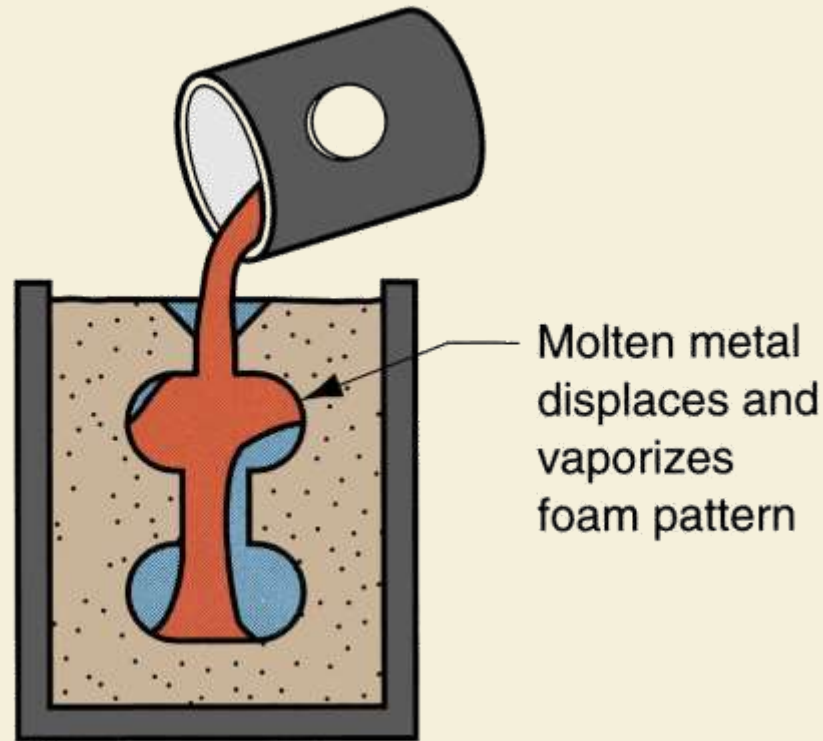


Figure 11.7 Expanded polystyrene casting process: (3) molten metal is poured into the portion of the pattern that forms the pouring cup and sprue. As the metal enters the mold, the polystyrene foam is vaporized ahead of the advancing liquid, thus the resulting mold cavity is filled.



Advantages and Disadvantages

Advantages of expanded polystyrene process:

- Pattern need not be removed from the mold
- Simplifies and speeds mold-making, because two mold halves are not required as in a conventional green-sand mold

Disadvantages:


- A new pattern is needed for every casting
- Economic justification of the process is highly dependent on cost of producing patterns



Expanded Polystyrene Process

Applications:

- Mass production of castings for automobile engines
- Automated and integrated manufacturing systems are used to
Mold the polystyrene foam patterns and
then
Feed them to the downstream casting
operation



Investment Casting (Lost Wax Process)

A pattern made of wax is coated with a refractory material to make mold, after which wax is melted away prior to pouring molten metal

"Investment" comes from a less familiar definition of "invest" - "to cover completely," which refers to coating of refractory material around wax pattern

It is a precision casting process - capable of producing castings of high accuracy and intricate detail

Investment Casting

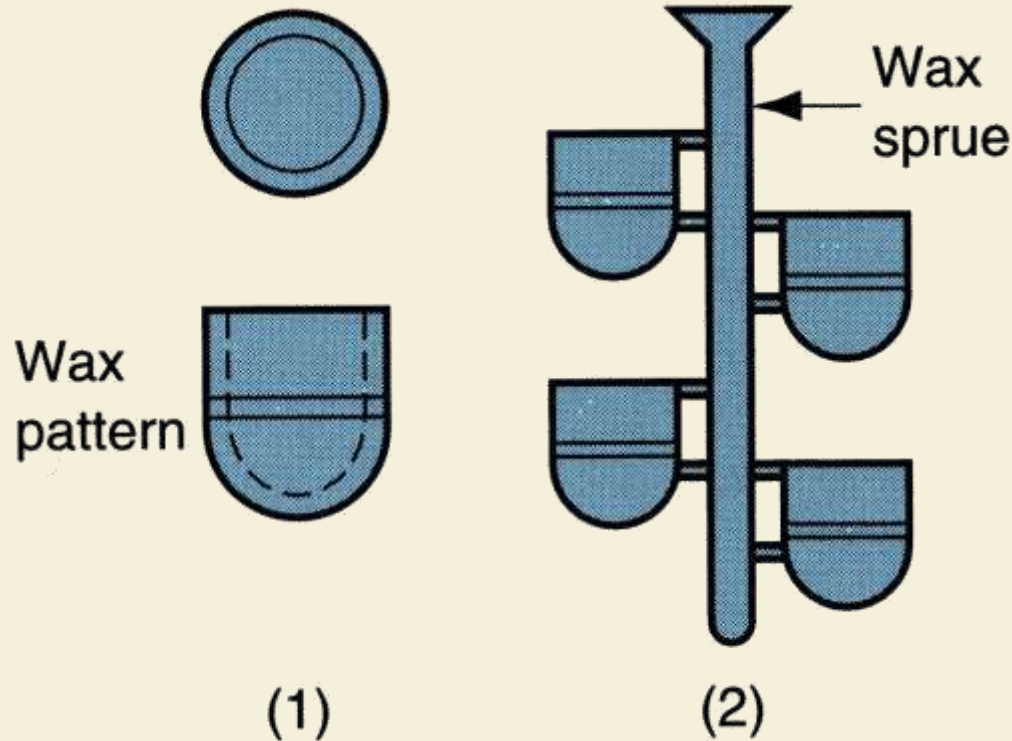


Figure 11.8 Steps in investment casting: (1) wax patterns are produced, (2) several patterns are attached to a sprue to form a pattern tree

Investment Casting

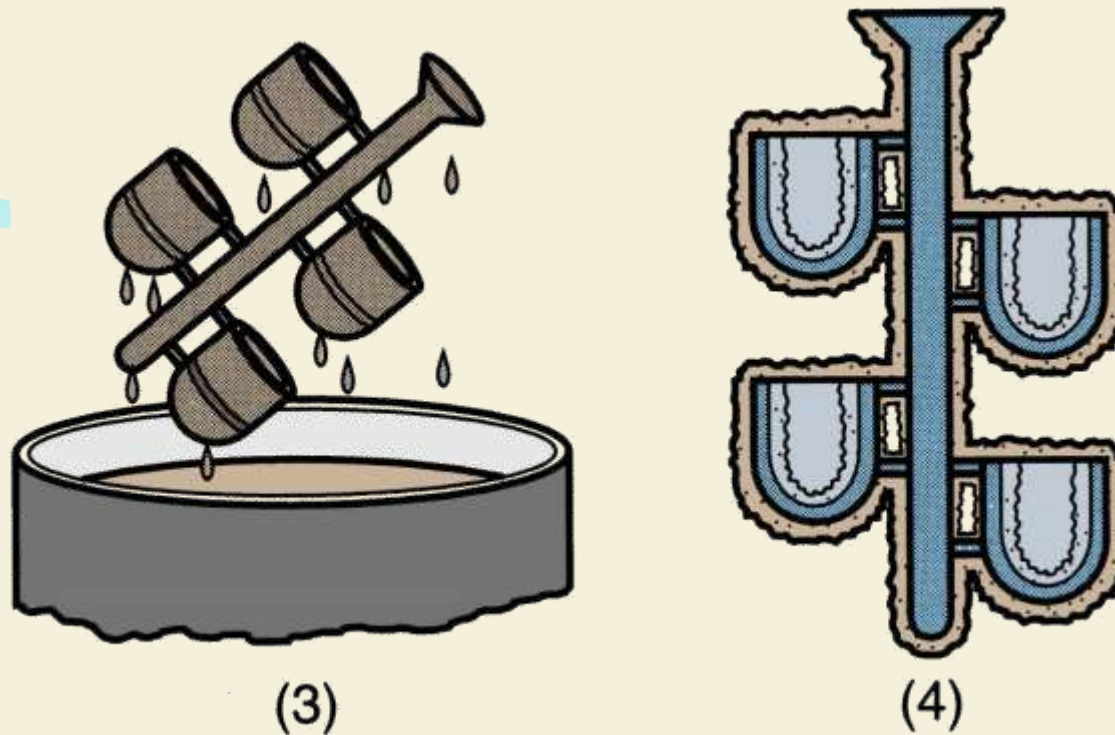


Figure 11.8 Steps in investment casting: (3) the pattern tree is coated with a thin layer of refractory material, (4) the full mold is formed by covering the coated tree with sufficient refractory material to make it rigid

Investment Casting

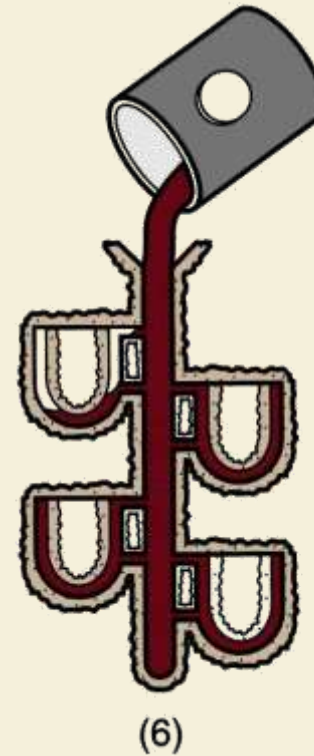
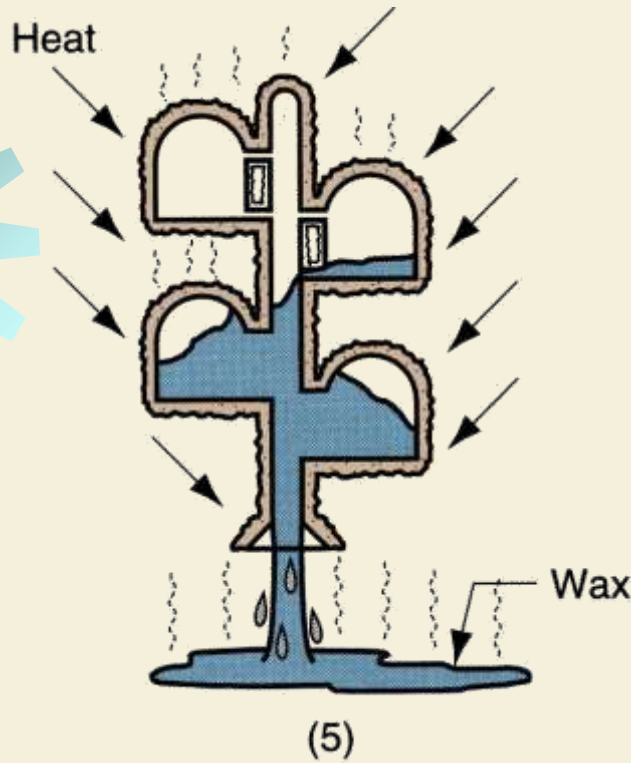


Figure 11.8 Steps in investment casting: (5) the mold is held in an inverted position and heated to melt the wax and permit it to drip out of the cavity, (6) the mold is preheated to a high temperature, the molten metal is poured, and it solidifies

Investment Casting



(7)

Figure 11.8 Steps in investment casting: (7) the mold is broken away from the finished casting and the parts are separated from the sprue

Investment Casting

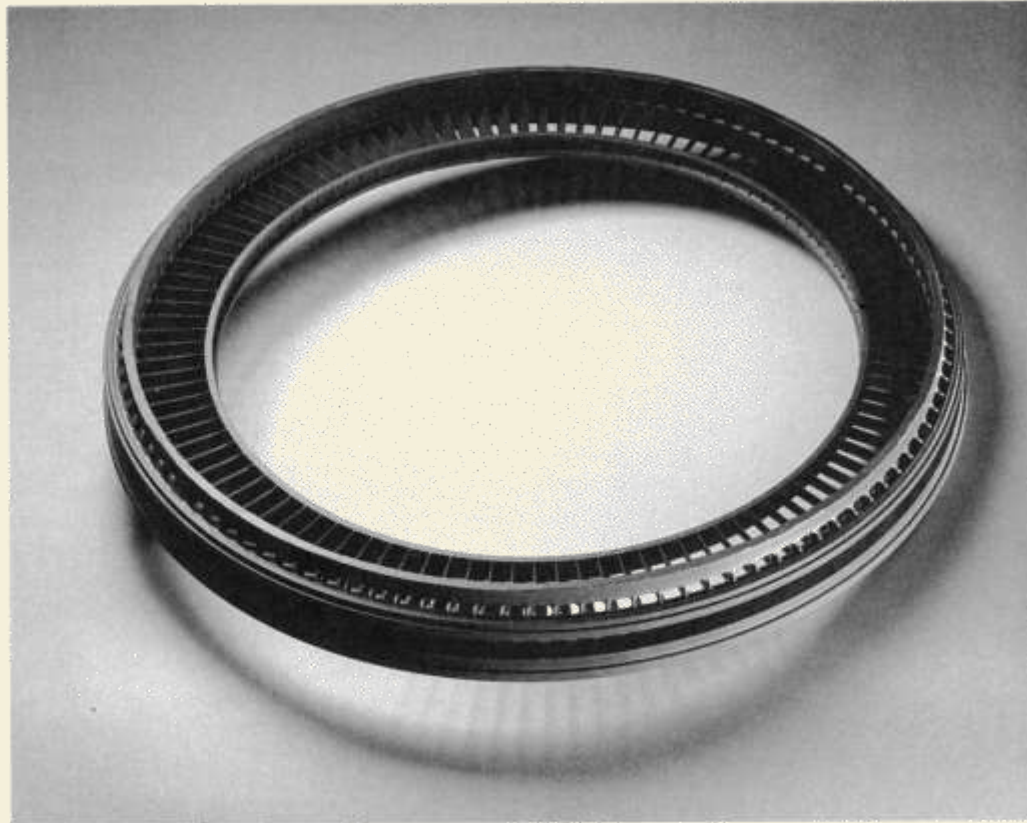


Figure 11 9 A one-piece compressor stator with 108 separate airfoils made by investment casting (photo courtesy of Howmet Corp.).



Advantages and Disadvantages

Advantages of investment casting:

- Parts of great complexity and intricacy can be cast
- Close dimensional control and good surface finish
- Wax can usually be recovered for reuse
- Additional machining is not normally required - this is a net shape process

Disadvantages

- Many processing steps are required
- Relatively expensive process



Plaster Mold Casting

Similar to sand casting except mold is made of plaster of Paris (gypsum - $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$)

In mold-making, plaster and water mixture is poured over plastic or metal pattern and allowed to set

- Wood patterns not generally used due to extended contact with water

Plaster mixture readily flows around pattern, capturing its fine details and good surface finish



Advantages and Disadvantages

Advantages of plaster mold casting:

- Good accuracy and surface finish
- Capability to make thin cross-sections

Disadvantages:

- Mold must be baked to remove moisture, which can cause problems in casting
- Mold strength is lost if over-baked
- Plaster molds cannot stand high temperatures, so limited to lower melting point alloys



Ceramic Mold Casting

Similar to plaster mold casting except that mold is made of refractory ceramic material that can withstand higher temperatures than plaster

Can be used to cast steels, cast irons, and other high-temperature alloys

Applications similar to those of plaster mold casting except for the metals cast

Advantages (good accuracy and finish) also similar