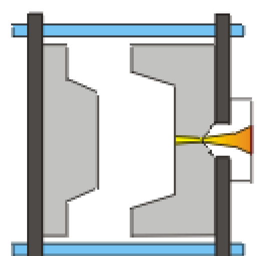
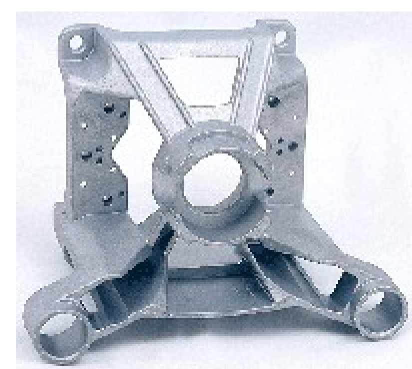
EDPT 601

Lecture 4
Casting Processes (cont'd)

Ref. : Ch 14 and 15 De Garmo

Ch 11 Kalpakjian





Prof N. El Mahallawy

Types of molding sands

Types of sand

- **Green Sand**
  It consists of silicia sand, mixed with approximately 3 per cent coal dust, 6 per cent clay and 3.5 percent water to act as a strength-enhancing binder.

- **CO_2 setting sand**
  It is a sodium silicate-based sand that chemically hardens when CO_2 gas is passed through it.

- **Core sand**
  It is clay free, but still need a binder. This is usually a resin that hardens with the application of heat.

Properties required in molding sands

- Uniform consistency
- Cohesion
- Refractoriness
- Permeability
- Collapsibility

Expendable Pattern Casting: Lost Foam or Full mold casting

Expendable Pattern Casting

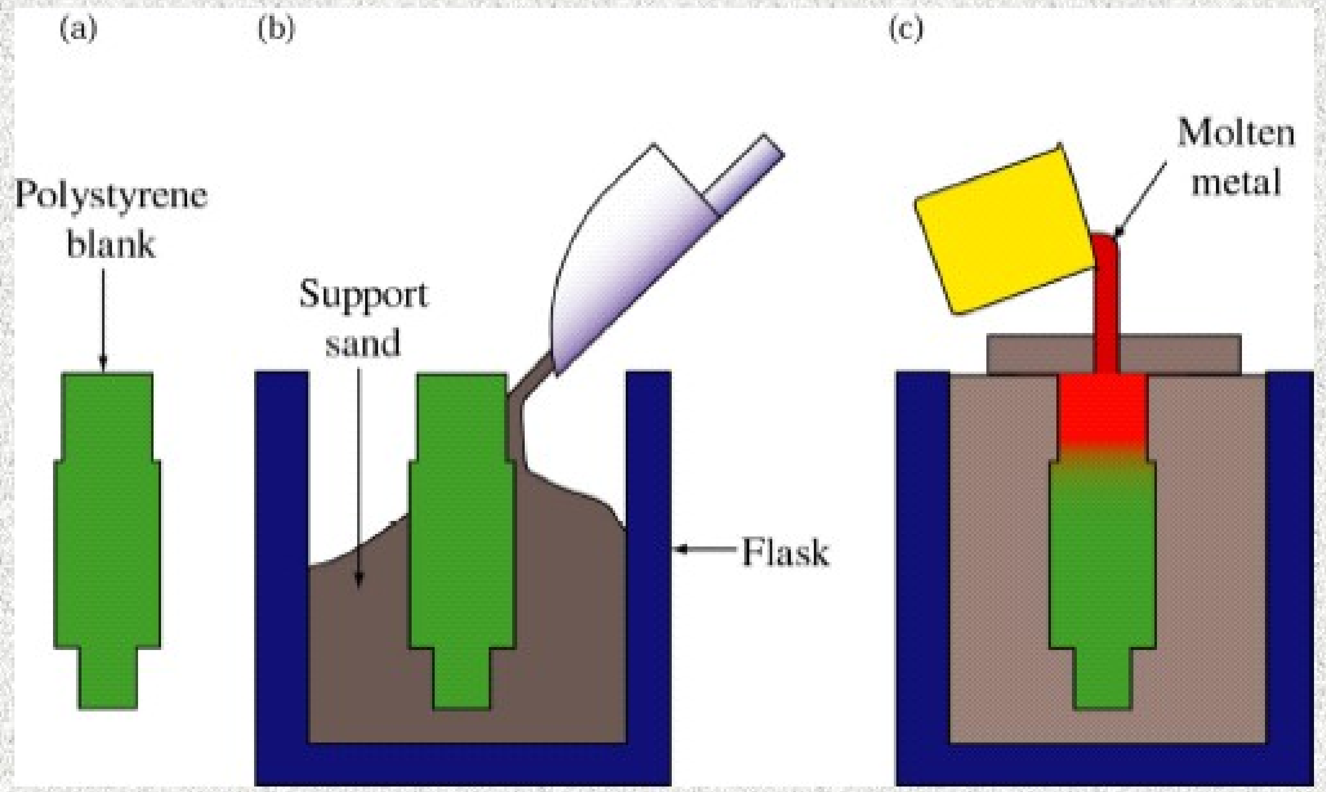
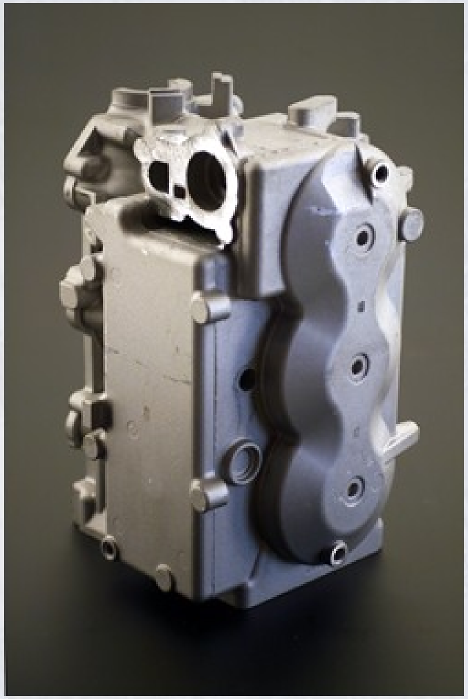


Figure 11.15 Schematic illustration of the expendable pattern casting process, also known as lost foam or evaporative casting.

Lost foam process

Evaporative Pattern Casting of an Engine Block

(a)



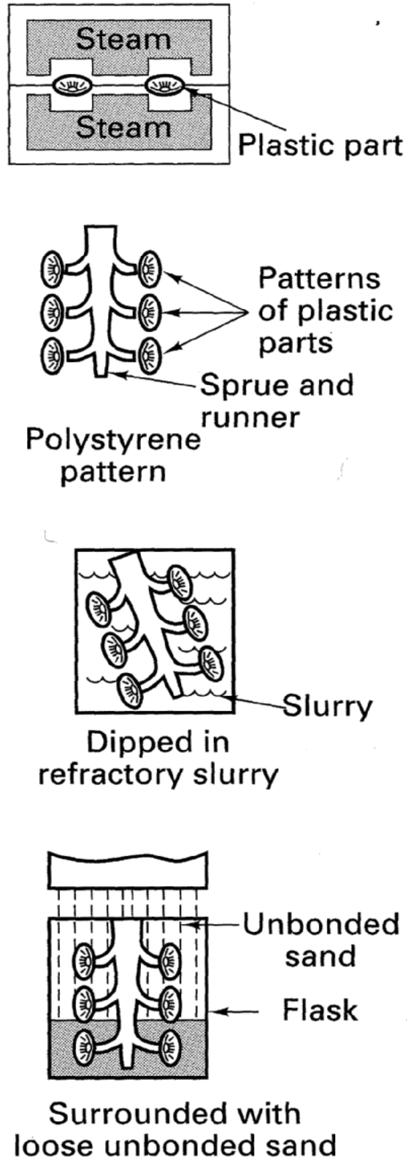
(b)

Figure 11.12 (a) Metal is poured into mold for lost-foam casting of a 60-hp. 3-cylinder marine engine; (b) finished engine block. Source: Courtesy of Mercury Marine.

In lost-foam casting process, the polystyrene pattern is dipped in a ceramic slurry, and the coated pattern is then surrounded with loose, unbonded sand

Schematic of the lost-foam casting process.

Mahallawy

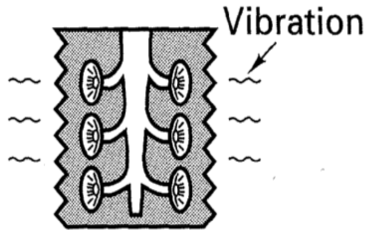


To make the foam parts, metal molds are used. Beads of polystyrene are heated and expanded in the mold to get parts.

A pattern containing a sprue, runners, risers, and parts is made from single or multiple pieces of foamed polystyrene plastic.

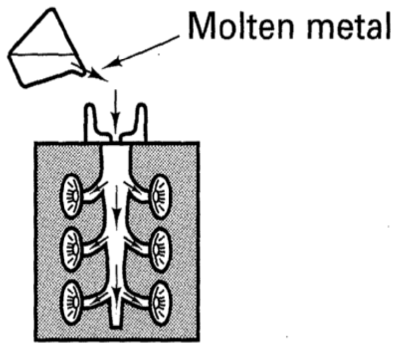
The polystyrene pattern is dipped in a ceramic slurry, which wets the surface and forms a coating about 0.005 inch thick.

The coated pattern is placed in a flask and surrounded with loose, unbonded sand.



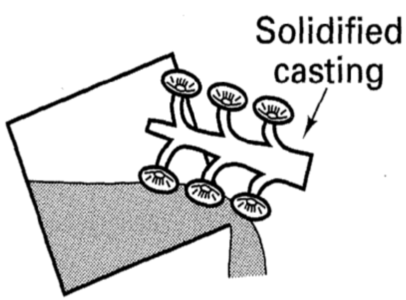
Compacted by vibration

The flask is vibrated so that the loose sand is compacted around the pattern.



Metal poured onto polystyrene pattern

During the pouring of molten metal, the hot metal vaporizes the pattern and fills the resulting cavity.

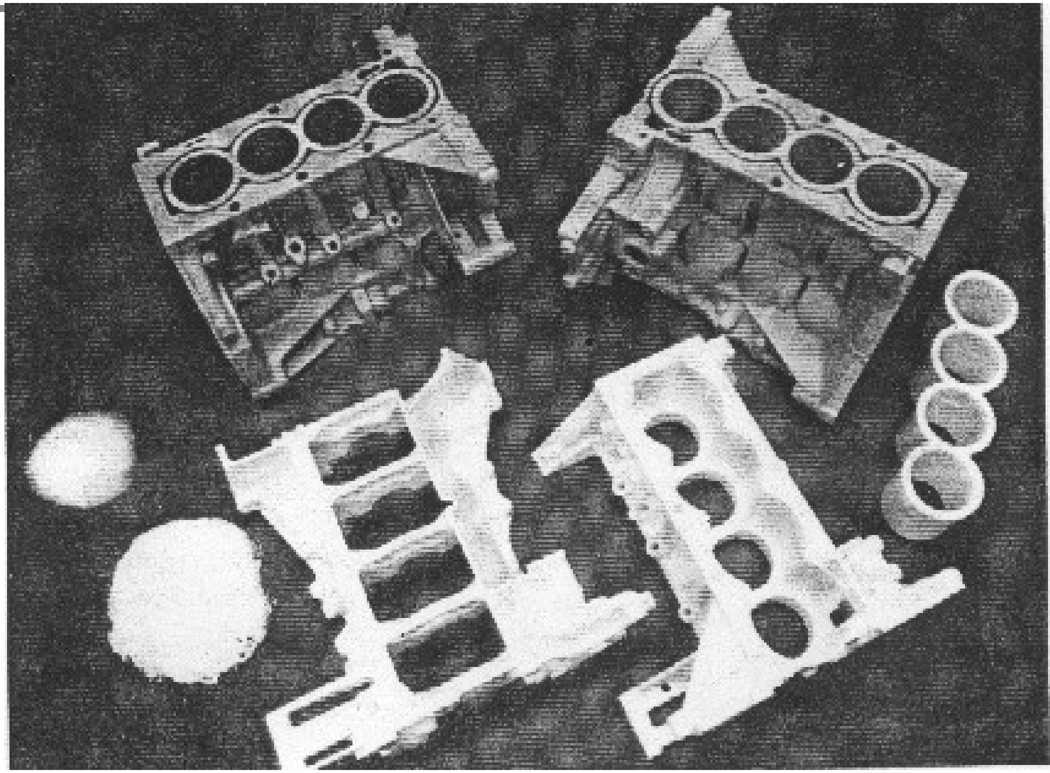


Casting removed and sand reclaimed

The solidified casting is removed from flask and the loose sand reclaimed.

Lost Foam Casting

- The stages of a lost-foam casting, proceeding counterclockwise from the lower left: polystyrene beads
- Expanded polystyrene pellets
- Three foam pattern segments
- An assembled and dipped
- Polystyrene pattern
- A finished metal casting which is a metal duplicate of the plystyrene pattern.



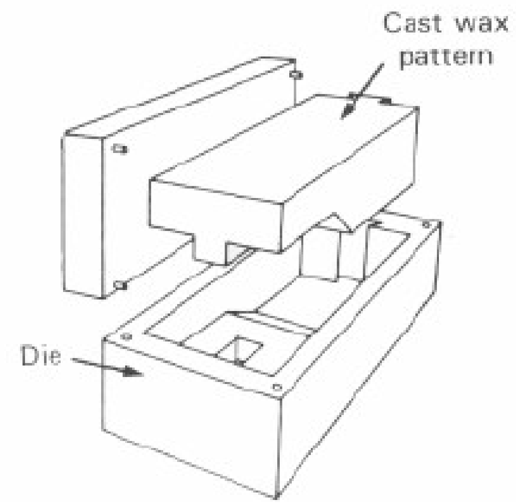
Lost wax Casting-investment casting

The development of high sophisticated machines like a gas turbine or a missile introduced new manufacturing problems. Such machine parts are made from difficult-to-cut materials. To meet this demands a modified form of a casting process, used by dentists to make gold fillings, was developed.

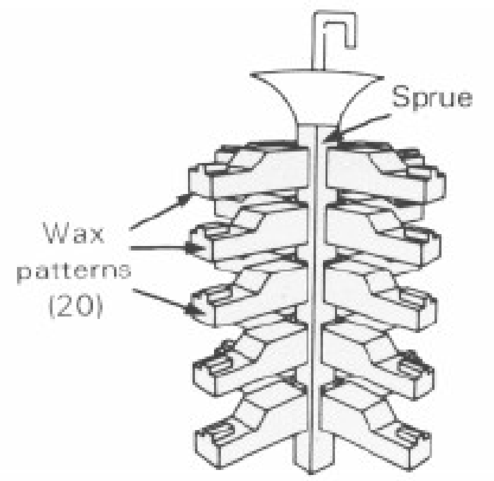
Investment casting involves the following steps:

(1) Make a pattern from a low melting point wax. Because it has such a low melting point (90 – 100°C) it is easy to cast the pattern in an aluminium die.

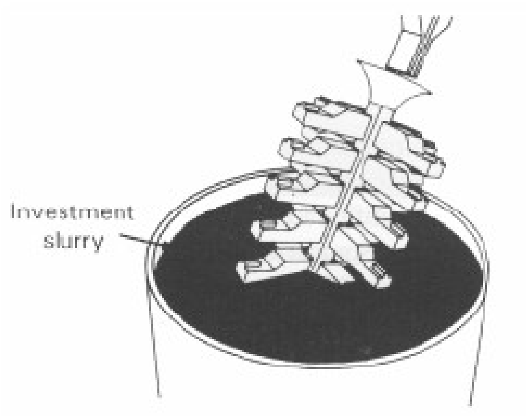
(2) When the wax has been solidified, the die is opened and the wax pattern is removed.



(3) When sufficient wax patterns have been made they are then assembled onto a central runner or sprue (stem), to form a tree-like structure.

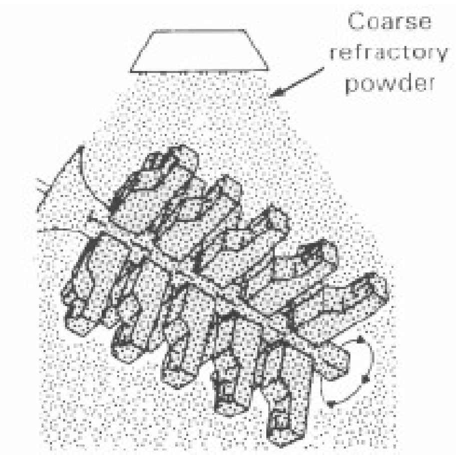


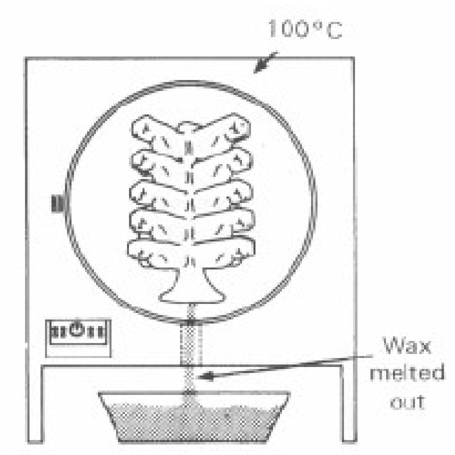
(4) This multi-pattern wax assembly is next submerged in a vat containing a fine ceramic-based slurry known as investment. The fineness of this slurry determines the surface finish of the finished components.



It is then coated (stuccoed) with a coarse refractory powder until a coating thickness of 5 to 10 mm has been built up over the whole wax assembly.

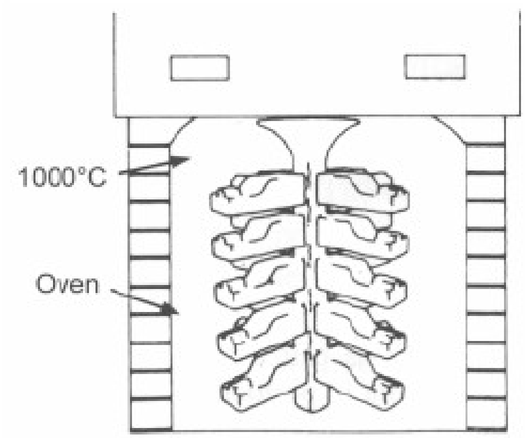
(5) When the investment has set and dried it is heated sufficiently for the wax tree to melt and run out (dewaxing), leaving cavities of the exact shape of the wax pattern in the investment.

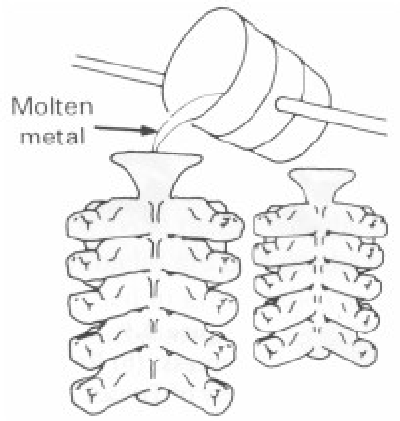




(6) The investment mould is next placed in an oven and heated to approximately 1000°C to vaporize any last vestiges of wax, and to fully harden off the investment.

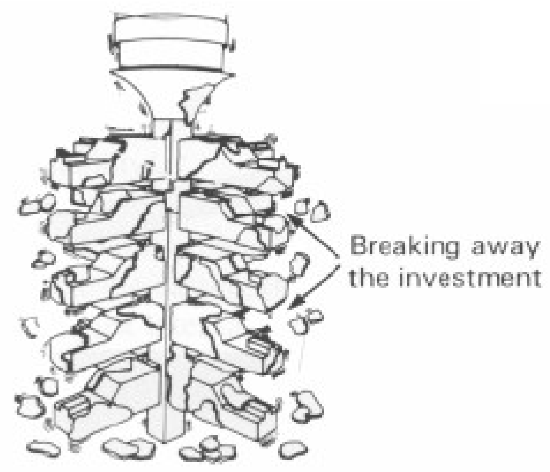
(7) The mould is removed from the oven and, while still hot, the molten metal is poured into it.





(8) When solidified, the cast tree of components is retrieved by breaking away (knocking out) the brittle investment material.

(9) Finally, each component is carefully cut from the tree, fettled and inspected before any subsequent machining processes that may be required.



Investment Casting Process-summary

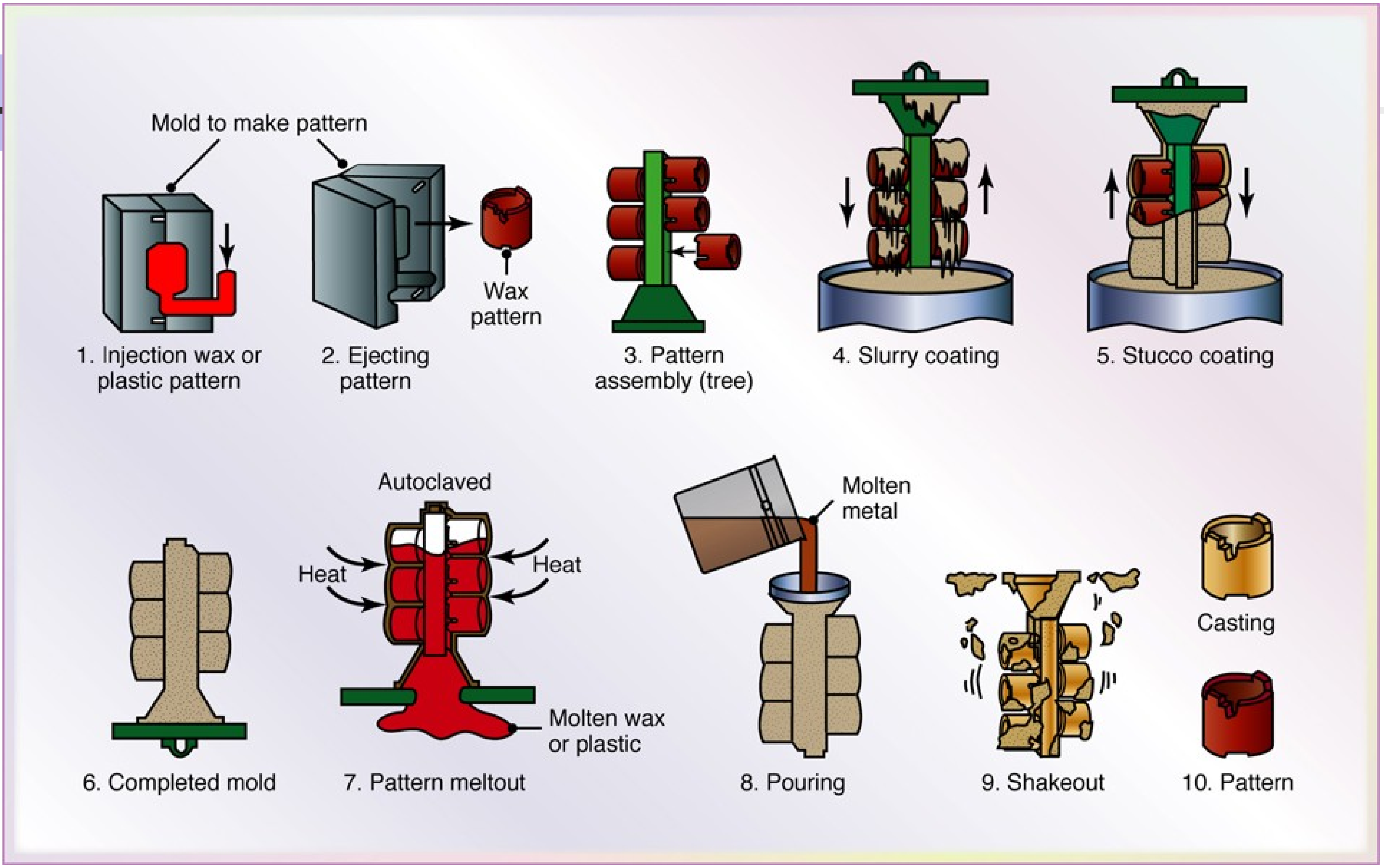
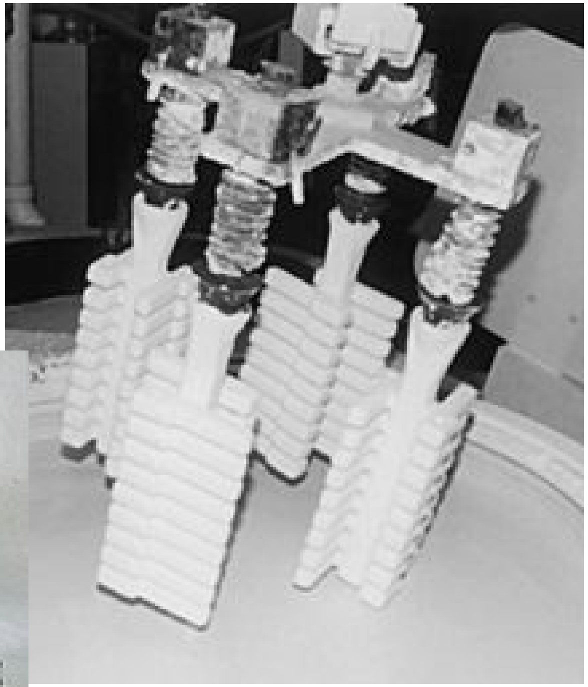
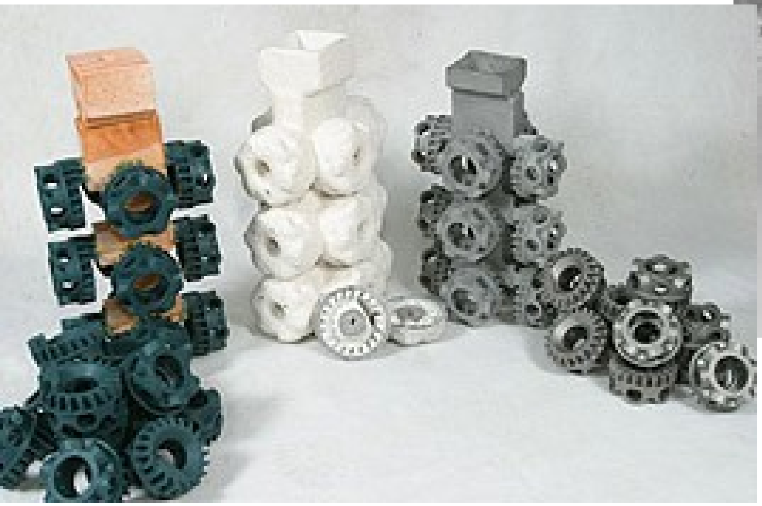


Figure 11.13 Schematic illustration of investment casting (lost-wax) process. Castings by this method can be made with very fine detail and from a variety of metals. *Source*: Courtesy of Steel Founder's Society of America.

Lost wax process





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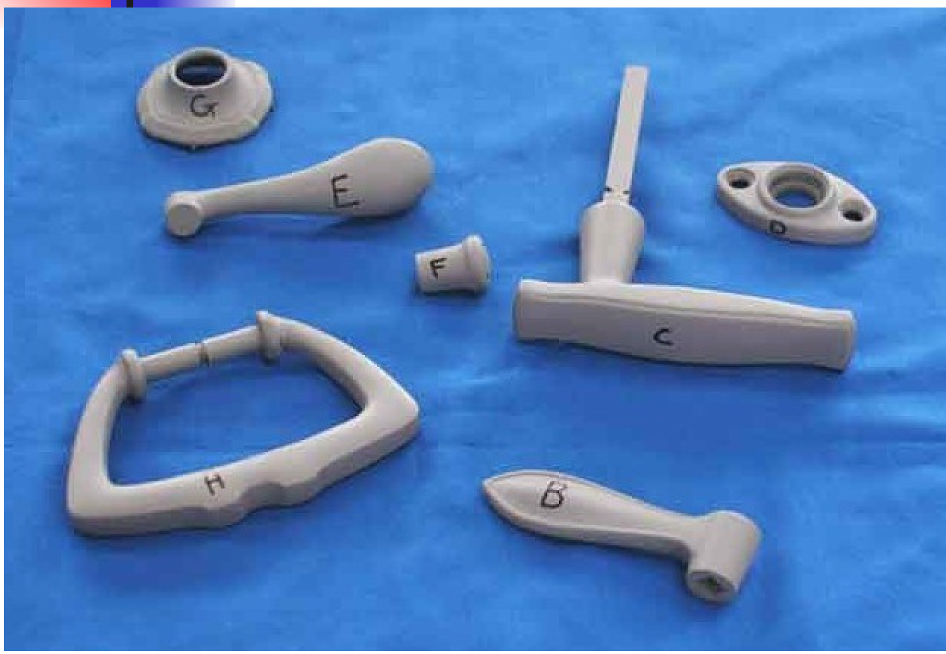
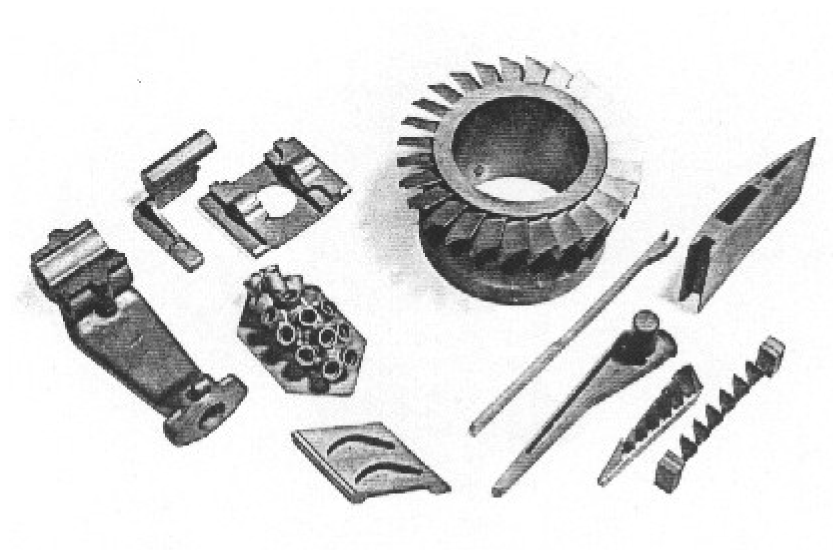
Mahallawy

Some products by Lost Wax Process





Some products produced by investment casting process.

Integrally Cast Rotor for a Gas Turbine

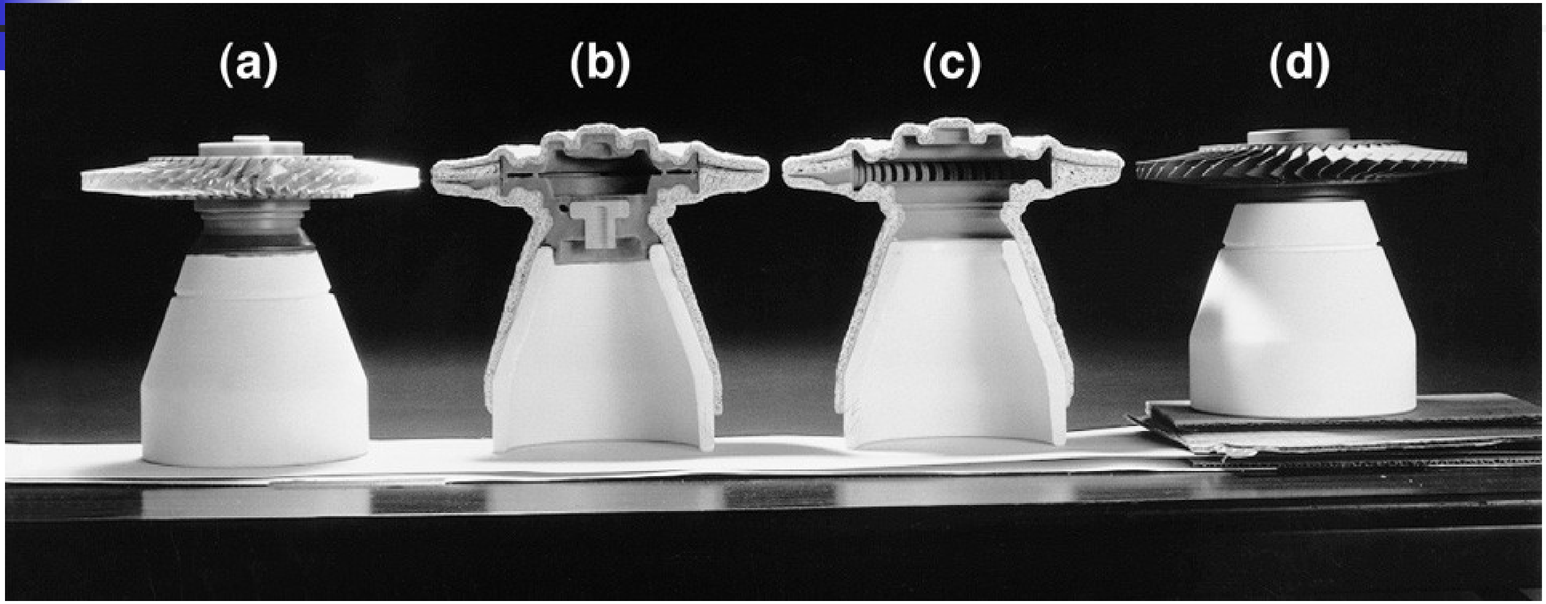


Figure 11.14 Investment casting of an integrally cast rotor for a gas turbine. (a) Wax pattern assembly. (b) Ceramic shell around wax pattern. (c) Wax is melted out and the mold is filled, under a vacuum, with molten superalloy. (d) The cast rotor, produced to net or near-net shape. *Source*: Courtesy of Howmet Corporation.

Vacuum Casting

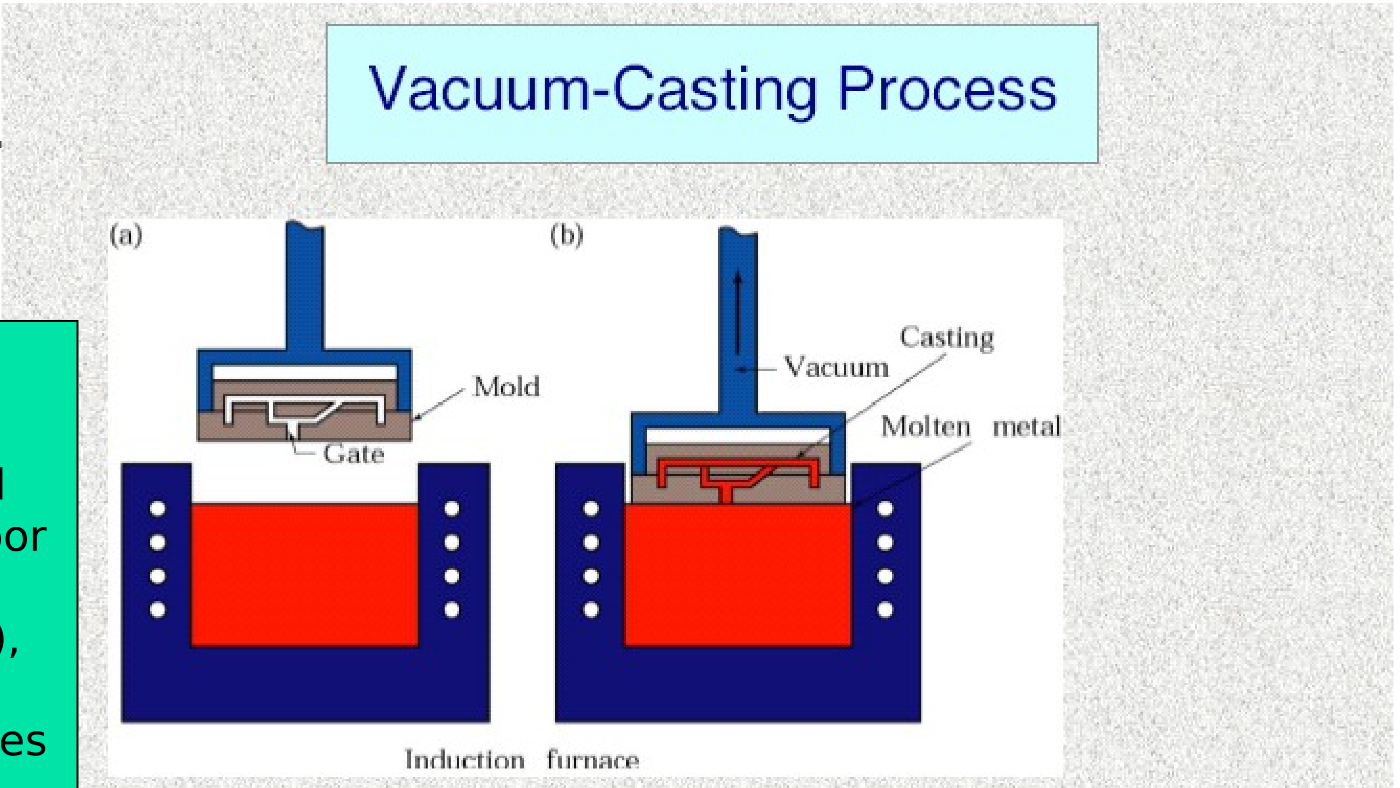


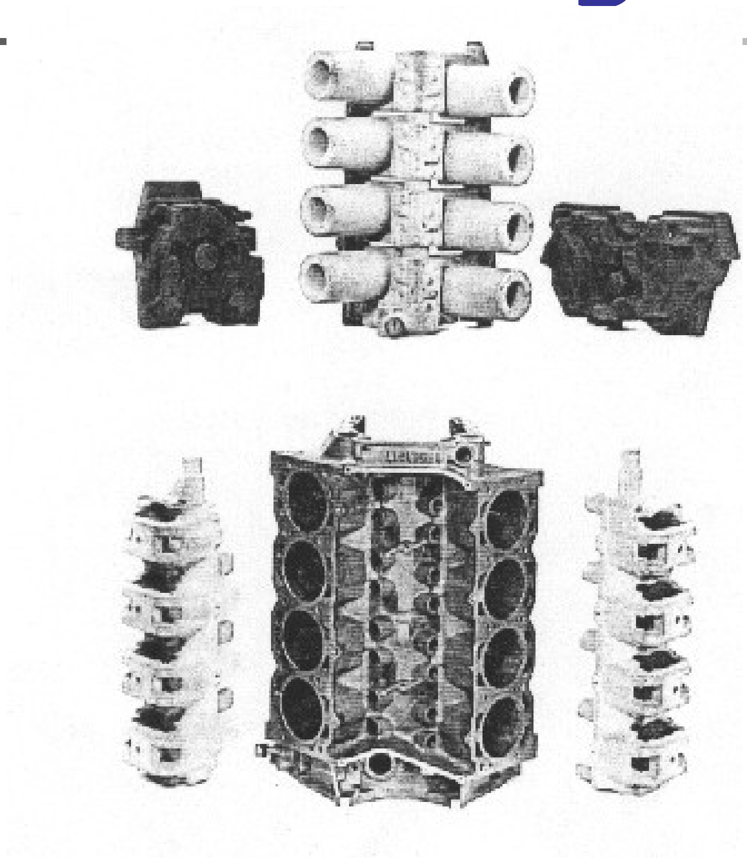
Figure 11.21 Schematic illustration of the vacuum-casting process. Note that the mold has a bottom gate. (a) Before and (b) after immersion of the mold into the molten metal. *Source*: From R. Blackburn, "Vacuum Casting Goes Commercial," *Advanced Materials and Processes*, February 1990, p. 18. ASM International.

Mold: fine sand
+ urethane molded
over metal dies and
cured with amine vapor
Suitable for
Thin walled(0.75mm),
Complex shapes
With uniform Properties

For reactive metals:
Al, Ti, Zr,
Superalloys for gas turbines

Mold is held with robot arm and
partially immersed into molten metal held
In an induction furnace

Vacuum Casting

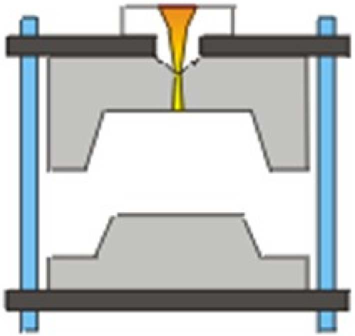


V-8 engine block (bottom center) and the five dry-sand cores that are used in the construction of its mold.
(courtesy of general motors corporation)

Permanent Mould or Die Casting

Properties:

- **Reusable**
- **made of metals that maintain their strength at elevated temperatures**
- **suitable for Al, Cu, Mg, steel in graphite mould**
- **provide higher cooling rates , affecting grain size**
- **cores are metallic or sand**
- **internal mould surfaces are coated with refractory slurry to :**
  - **act as parting agent**
  - **increase mould life**
  - **act as thermal barrier**



Permanent Mould Casting

- use ejectors and water cooled dies, vents on one side of the die
- good surface finish, close tolerances, uniform and good mechanical properties, high production rates
- die life depends on metal being cast -

  approx 10 000 brass castings and several millions for zinc castings

  ex:
  - cylinder heads
  - connecting rods
  - gear blanks
  - automobile pistons

Properties and Applications of Die-Casting Alloys

TABLE 11.3

Properties and Typical Applications of Some Common Die-Casting Alloys

Alloy	Ultimate tensile strength (MPa)	Yield strength (MPa)	Elongation in 50 mm (%)	Applications
Aluminum 380 (3.5 Cu - 8.5 Si)	320	160	2.5	Appliances, automotive components, electrical motor frames and housings
13 (12 Si)	300	150	2.5	Complex shapes with thin walls, parts requiring strength at elevated temperatures
Brass 858 (60 Cu)	380	200	15	Plumbing fixtures, lock hardware, bushings, ornamental castings
Magnesium AZ91B (9 Al - 0.7 Zn)	230	160	3	Power tools, automotive parts, sporting goods
Zinc No. 3 (4 Al)	280	-	10	Automotive parts, office equipment, household utensils, building hardware, toys
No. 5 (4 Al - 1 Cu)	320	-	7	Appliances, automotive parts, building hardware, business equipment

Source: American Die Casting Institute.

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Die-Casting Examples

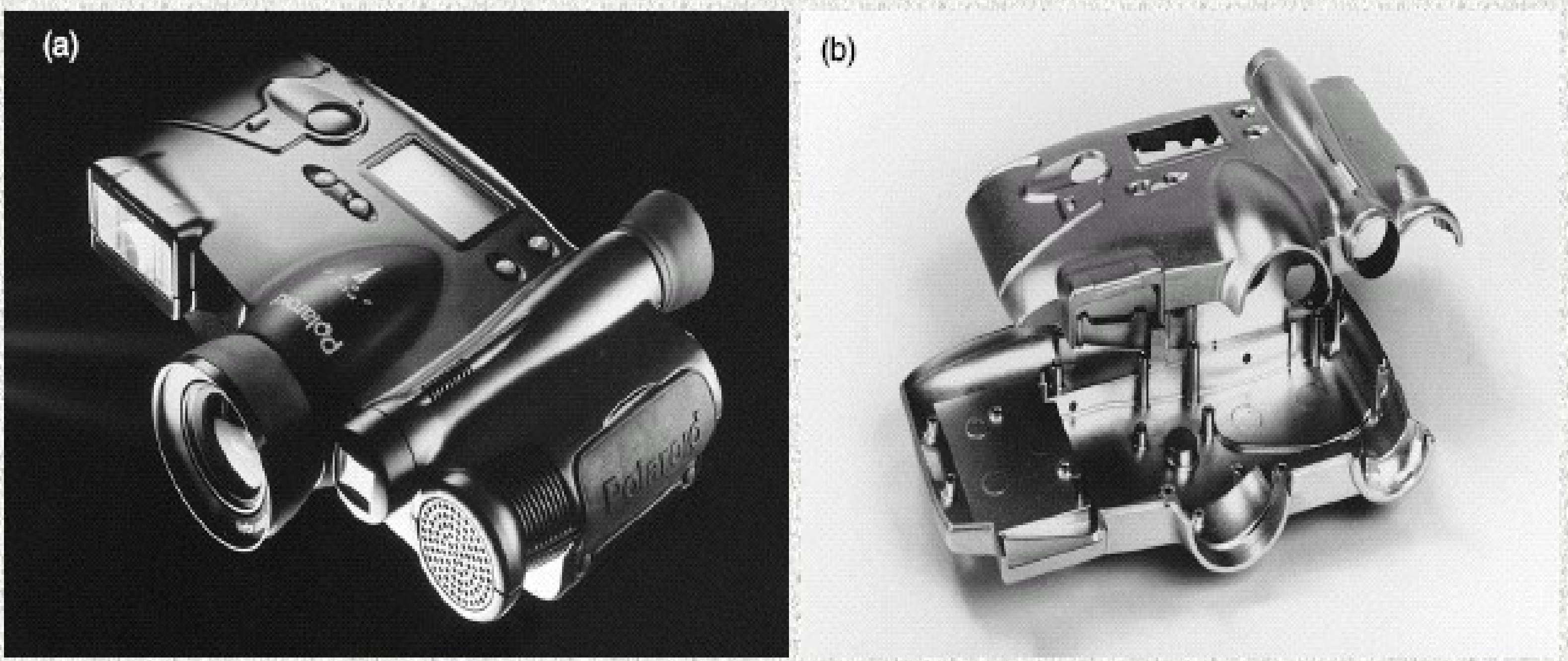
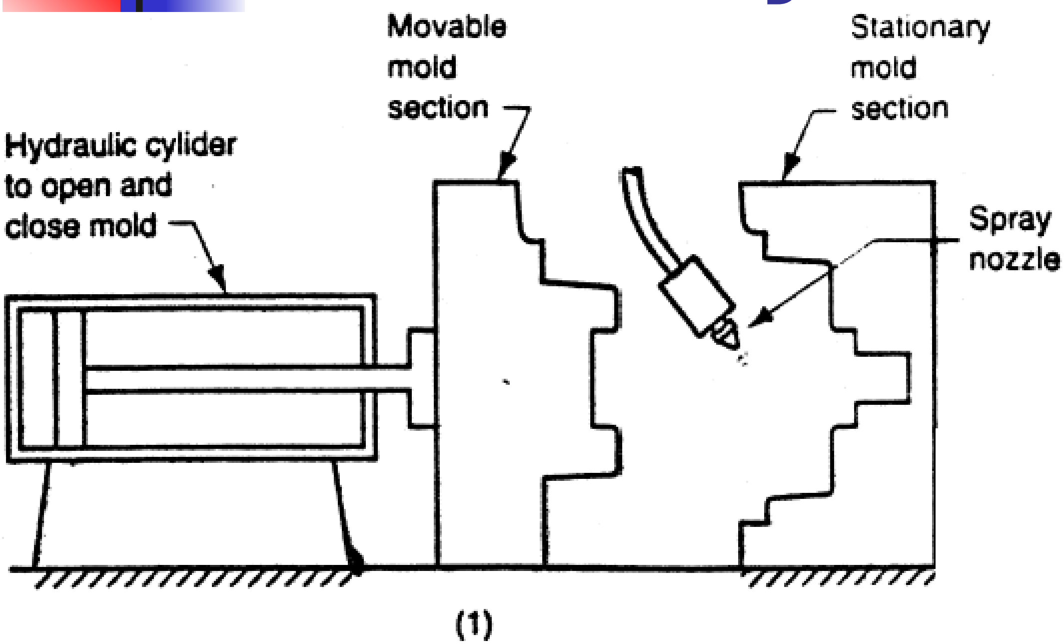
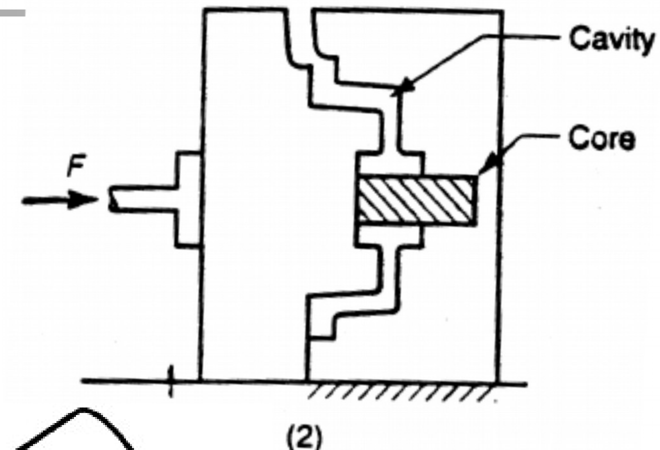


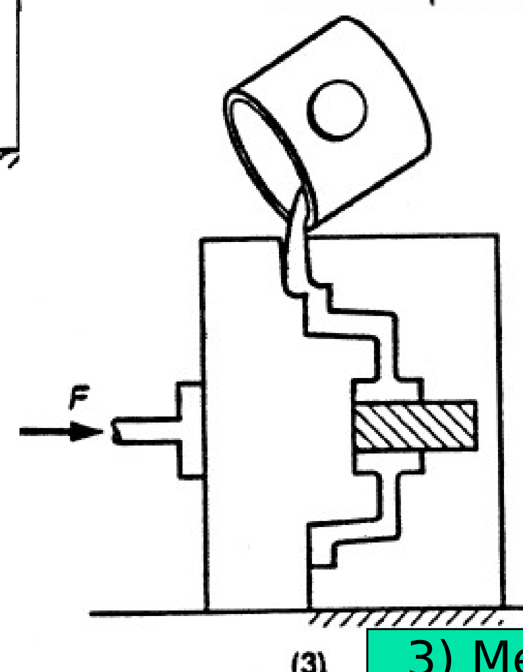
Figure 11.1 (a) The Polaroid PDC-2000 digital camera with a AZ91D die-cast, high purity magnesium case. (b) Two-piece Polaroid camera case made by the hot-chamber die casting process. *Source*: Courtesy of Polaroid Corporation and Chicago White Metal Casting, Inc.

1. Gravity Die Casting





Gravity die casting
No pressure is applied



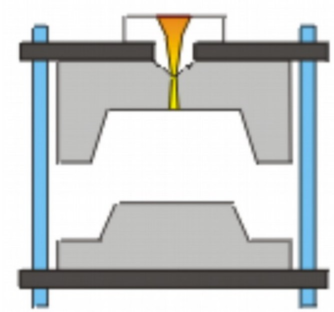
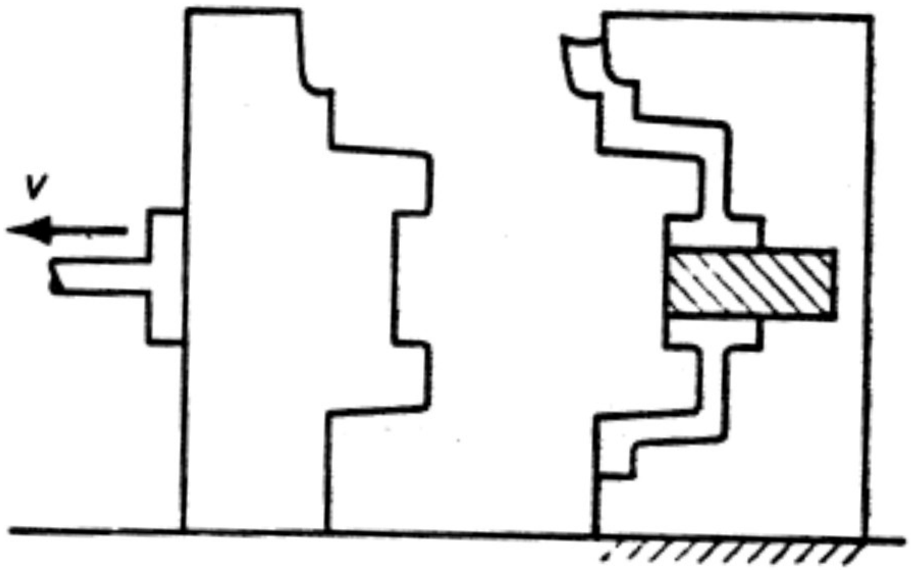


Figure 3.10 Permanent mold casting process.
(1) Mold is preheated and coated.
(2) Cores (if used) are inserted and mold is closed.

3) Metal is poured

Die Casting



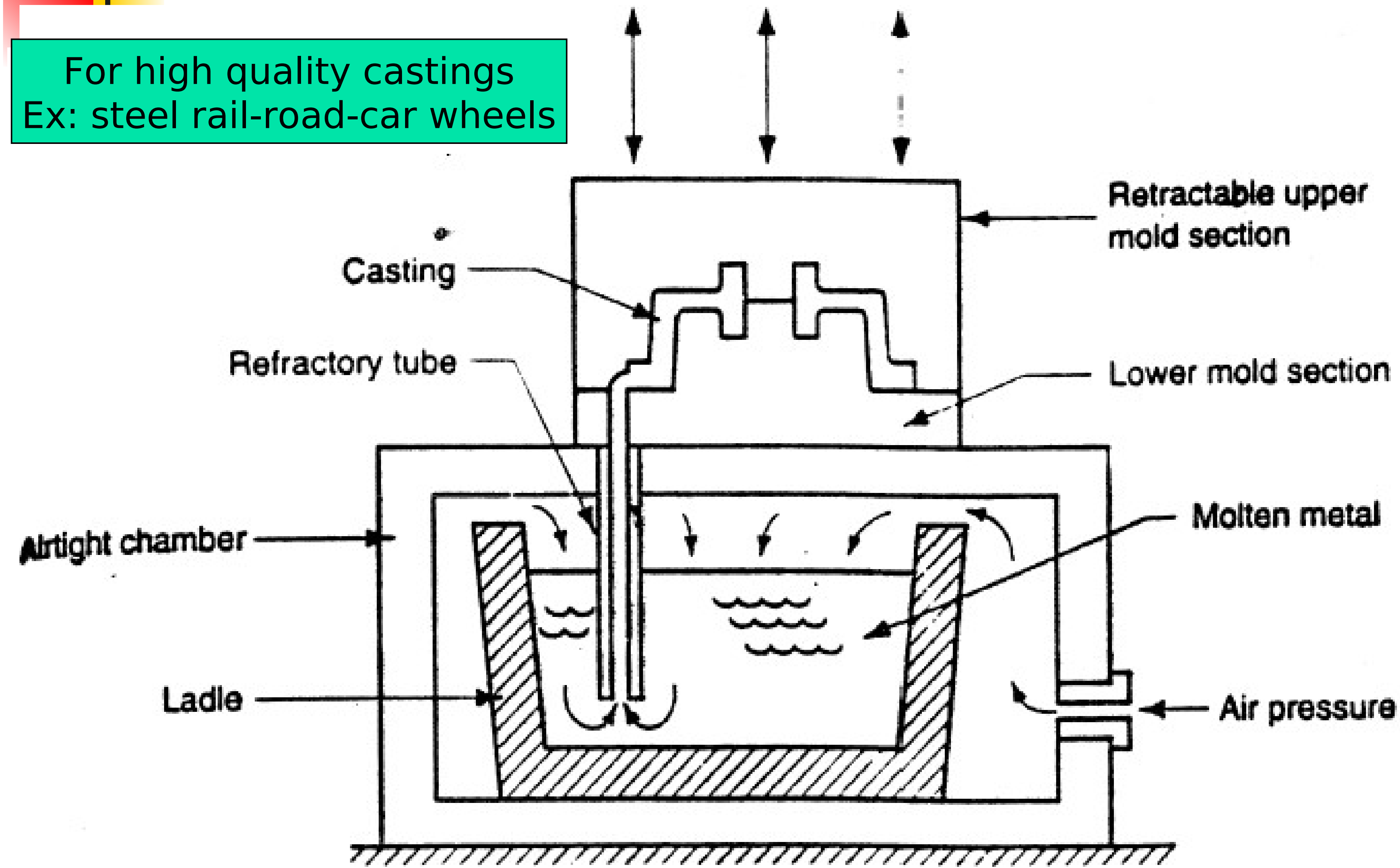
(4)

(5)

4) Mold is opened after solidification
5) Casting is removed

2. Low-Pressure Permanent Mold process

For high quality castings
Ex: steel rail-road-car wheels

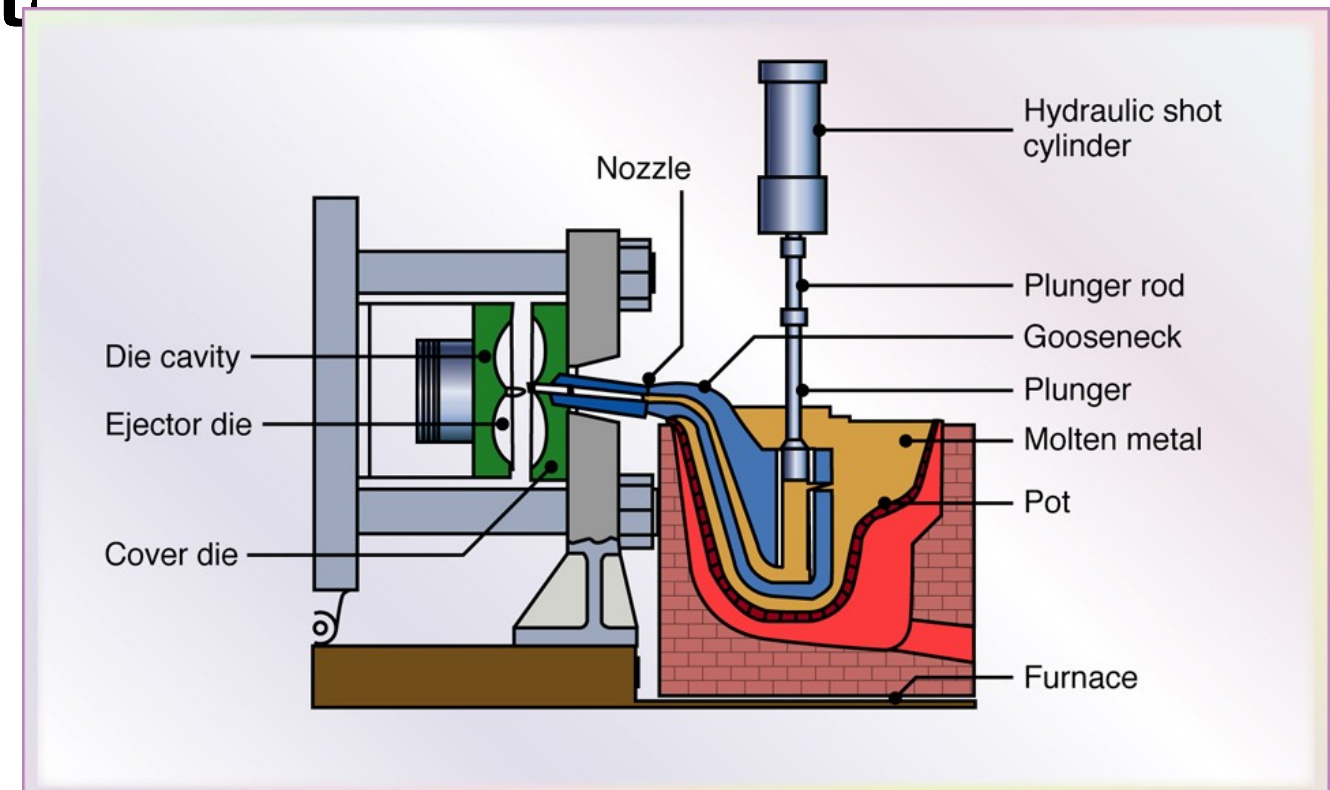


3. Hot Chamber Pressure Die Casting

- **Suitable for zinc, lead, tin castings ex: zipper t**

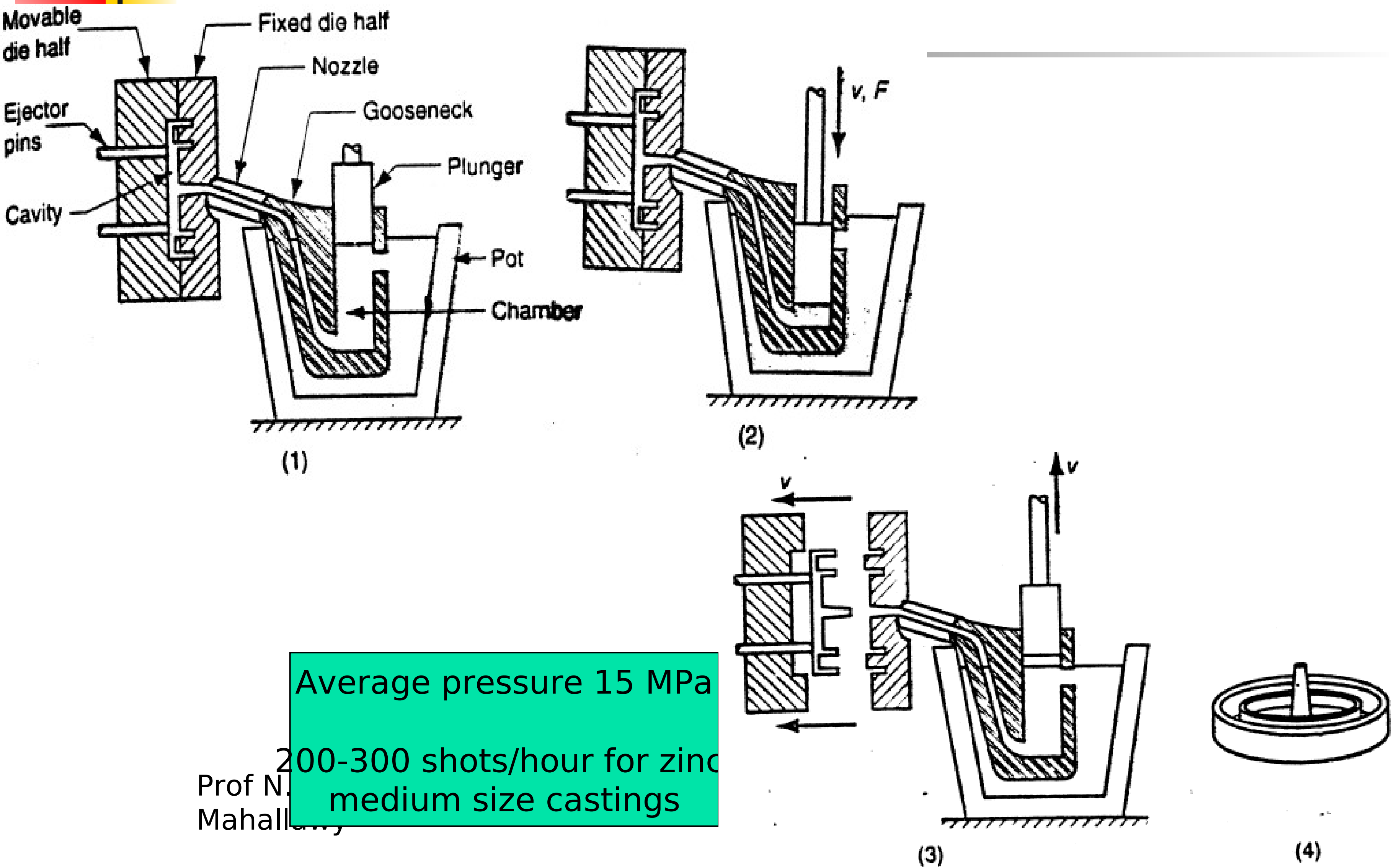
General view
of the Machine

Not suitable
for Al, Cu alloys



Schematic illustration of the hot-chamber die-casting process.

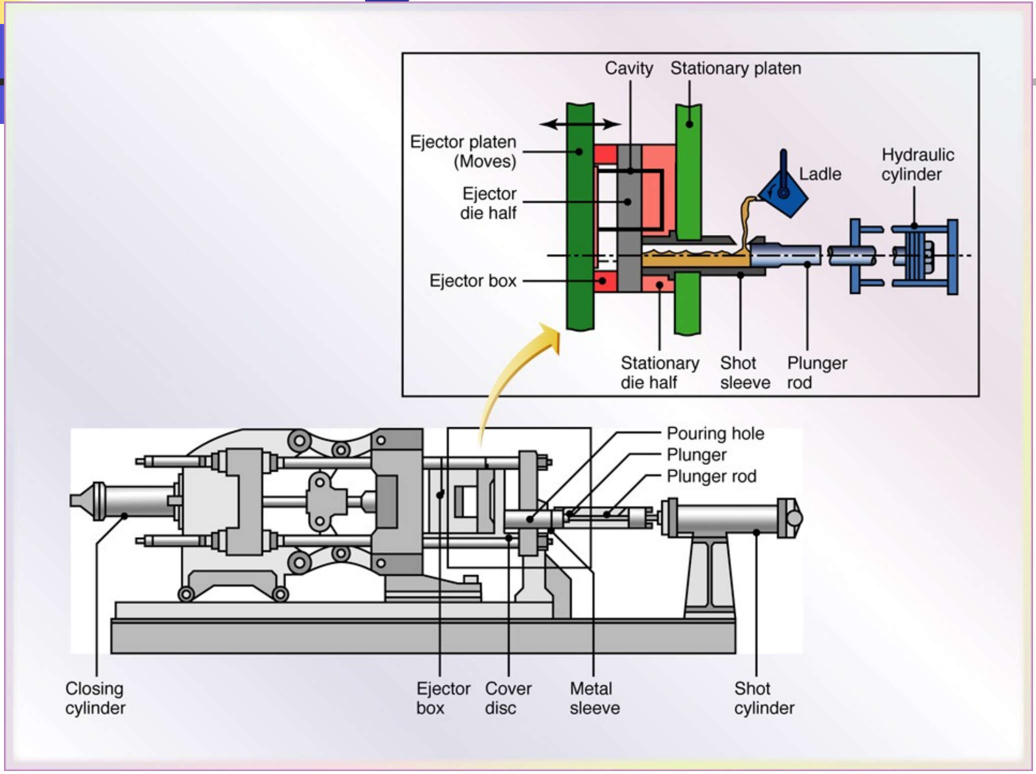
Hot Chamber Pressure Die Casting – cycle details



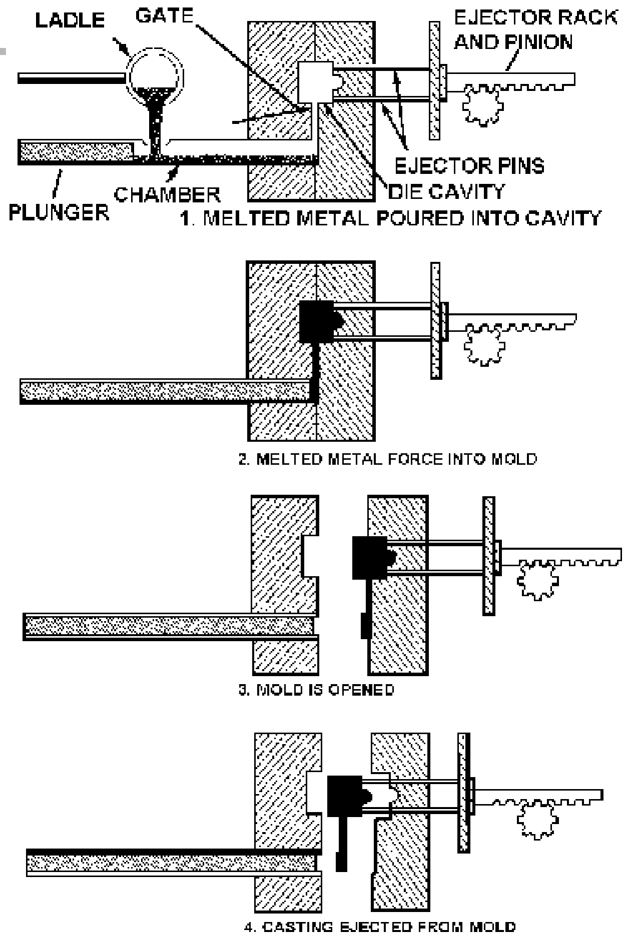
Average pressure 15 MPa

200-300 shots/hour for zinc medium size castings

4. Cold Chamber Die Casting



Schematic illustration of the cold-chamber die-casting process. These machines are large compared to the size of the casting, because high forces are required to keep the two halves of the dies closed under pressure.



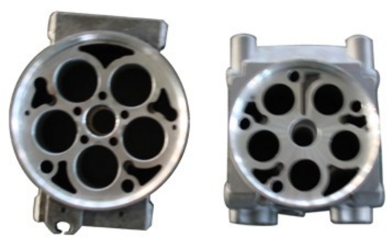
Suitable for: brass, Al, Mg
requiring higher pressures and melting temperatures
d avoiding reaction between steel parts and molten metal

Pressure
20 to 70 MPa

Cold Chamber Die Casting

- High production rates (300 /hr)
- Economical for large production Qty
- Close tolerances (±0.076 mm)
- Good surface finish (1 micron)
- Very thin sections (0.5 mm)
- Rapid cooling (small grain size & good strength)

Die Castings



Al and Zinc pressure die castings

Centrifugal Casting

- True centrifugal
- Semi-centrifugal
- Centrifuge

Centrifugal Casting Process

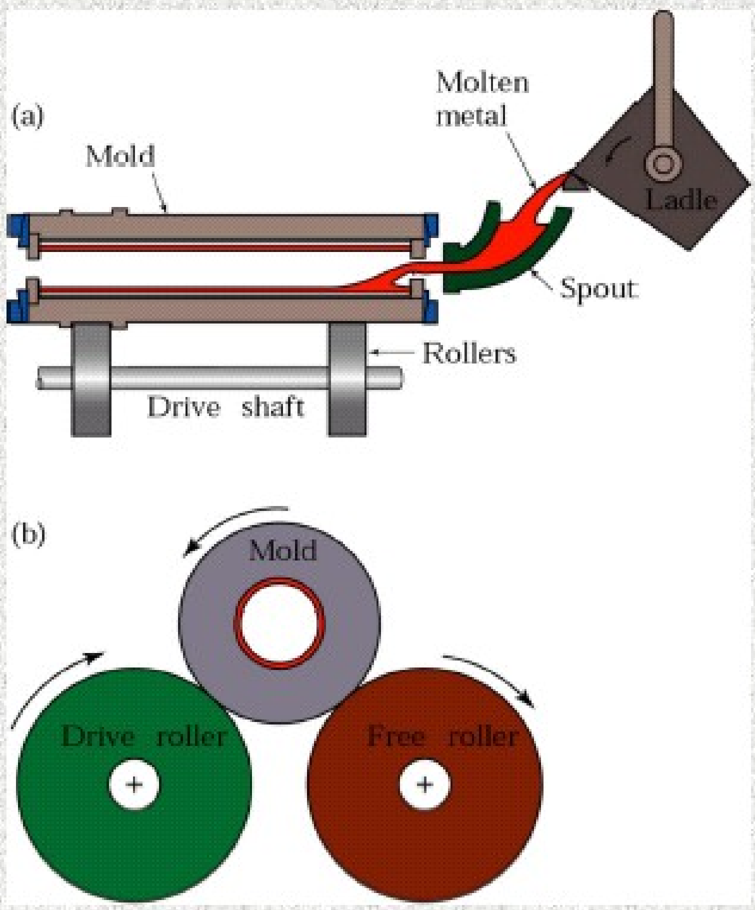
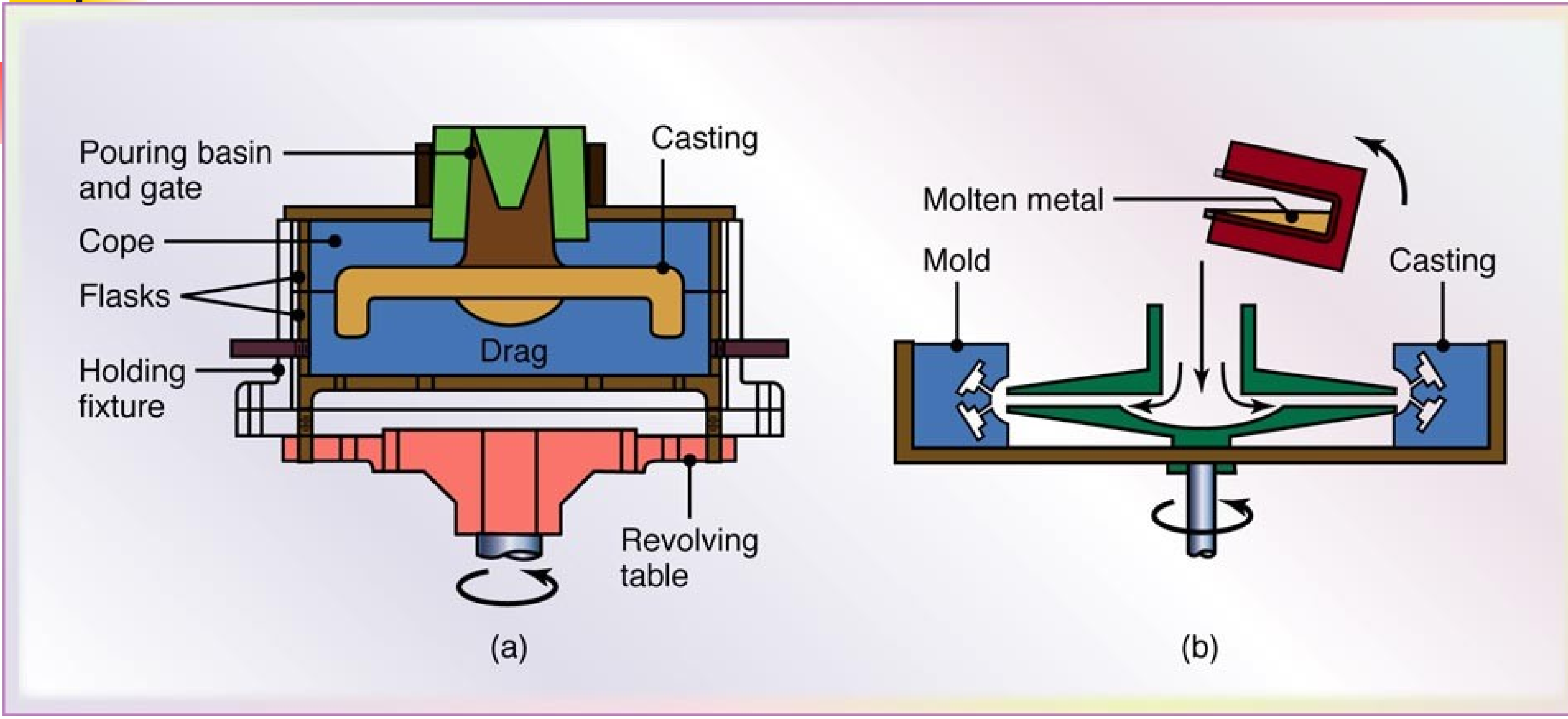


Figure 11.27 Schematic illustration of the centrifugal casting process. Pipes, cylinder liners, and similarly shaped parts can be cast with this process.

Rotational speed around 1000 rpm
Thickness of the pipe is determined by the amount of liquid metal

Semicentrifugal Casting and Casting by Centrifuging

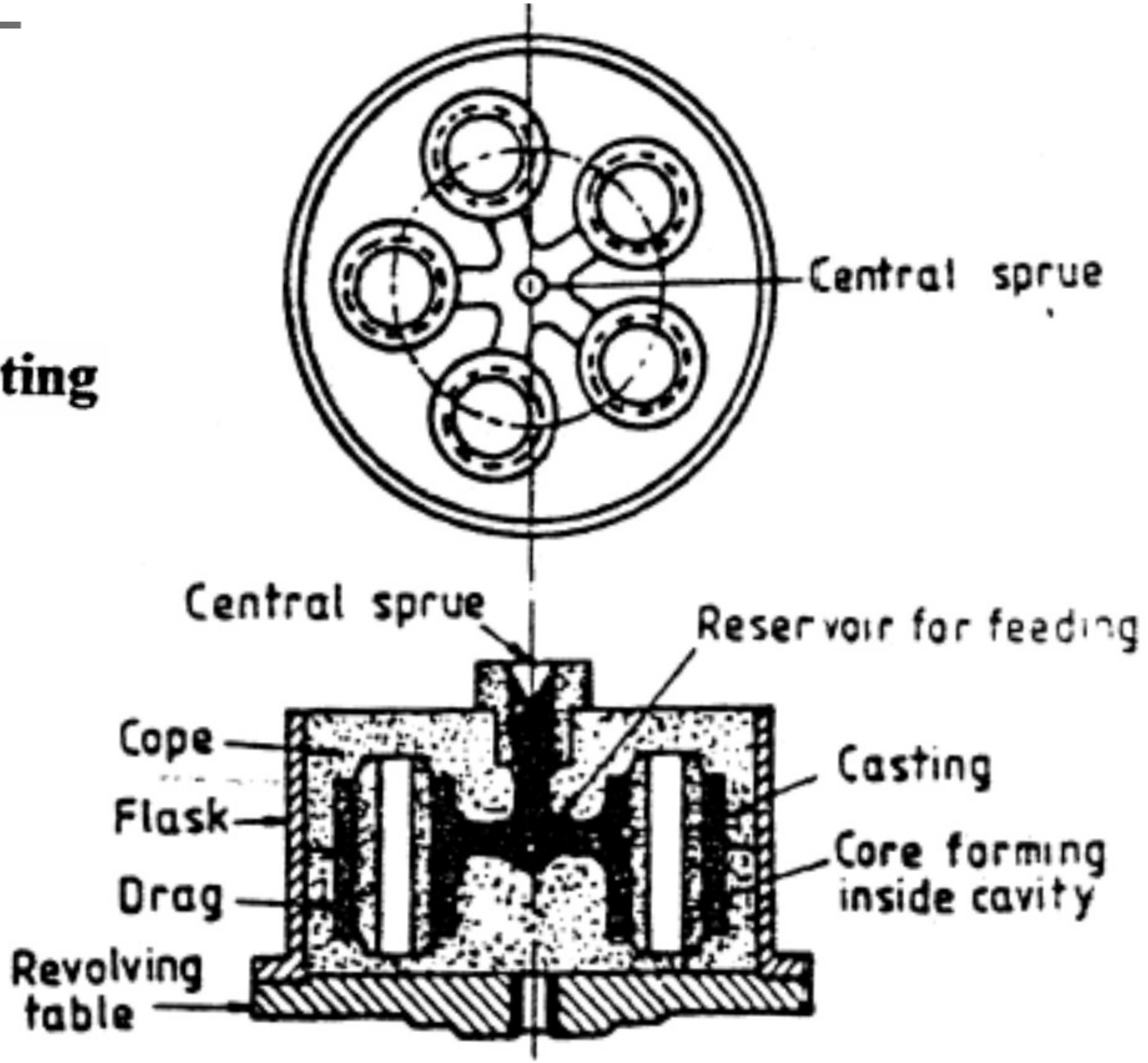


(a) Schematic illustration of the semicentrifugal casting process. Wheels with spokes can be cast by this process. (b) Schematic illustration of casting by centrifuging. The molds are placed at the periphery of the machine, and the molten metal is forced into the molds by centrifugal force.

Centrifuge Casting

Figure 3.16 Centrifuge casting

Not necessary cylindrical shapes



Continuous Casting

steel billets

Al billets

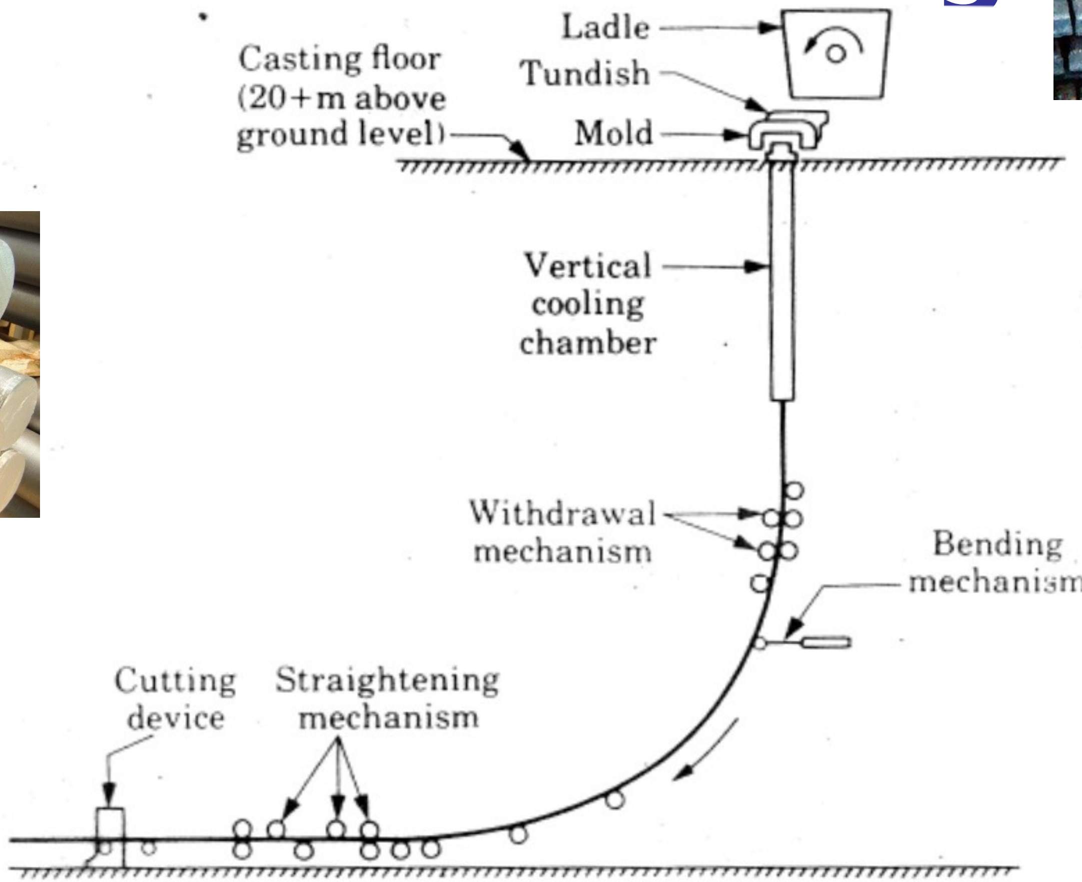
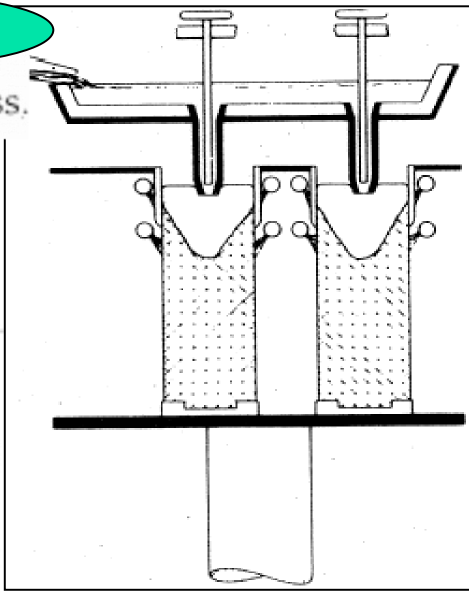


FIGURE 5.21 Schematic illustration of continuous casting of steel. Because of high efficiency and favorable economics, continuous casting is rapidly replacing traditional steelmaking processes, as well as those for nonferrous metals. *Source:* USX Corporation.

Figure 6.20
Casting aluminum ingots by the direct-chill process.



Continuous Casting

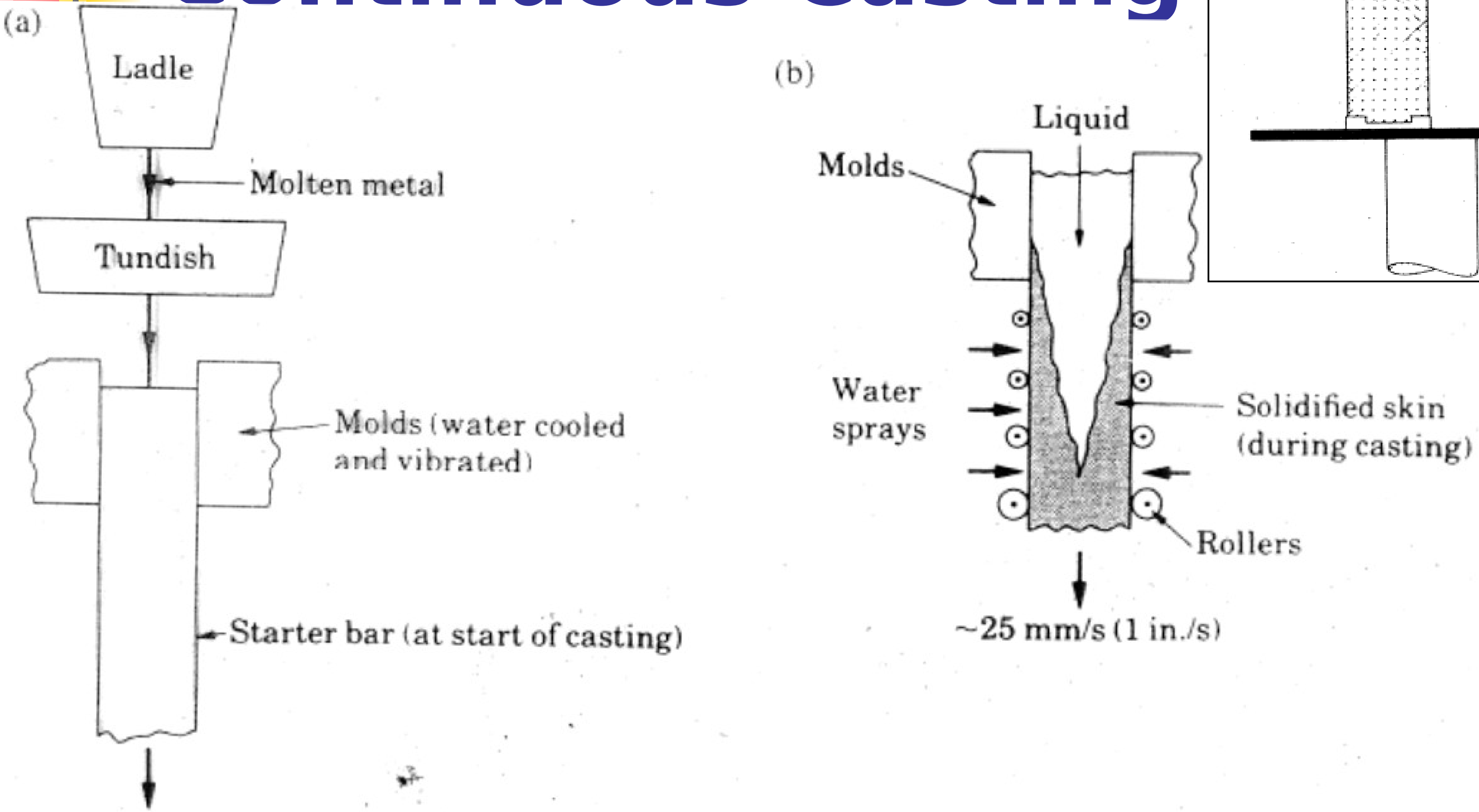


FIGURE 5.22 (a) Method of starting a continuous casting process with a starter bar, and (b) the cross-section of a continuously cast metal as it begins to solidify.

CASTING PROCESSES, THEIR ADVANTAGES AND LIMITATIONS

PROCESS	ADVANTAGES	LIMITATIONS
Sand	Almost any metal is cast; no limit to size, shape or weight; low tooling cost.	Some finishing required; somewhat coarse finish; wide tolerances.
Shell mold	Good dimensional accuracy and surface finish; high production rate.	Part size limited; expensive patterns and equipment required.
Expandable pattern	Most metals cast with no limit to size; complex shapes.	Patterns have low strength and can be costly for low quantities.
Plaster mold	Intricate shapes; good dimensional accuracy and finish; low porosity.	Limited to nonferrous metals; limited size and volume of production; mold making time relatively long.
Ceramic mold	Intricate shapes; close tolerance parts; good surface finish.	Limited size.
Investment	Intricate shapes; excellent surface finish and accuracy; almost any metal cast.	Part size limited; expensive patterns, molds, and labor.
Permanent mold	Good surface finish and dimensional accuracy; low porosity; high production rate.	High mold cost; limited shape and intricacy; not suitable for high-melting-point metals.
Die	Excellent dimensional accuracy and surface finish; high production rate.	Die cost is high; part size limited; usually limited to nonferrous metals; long lead time.
Centrifugal	Large cylindrical parts with good quality; high production rate.	Equipment is expensive; part shape limited.

Review questions

- Sketch the steps of the following processes: shell casting- cold chamber die casting- gravity die casting- lost wax process- mention typical castings for each process
- List the advantages and limitations of die casting- lost foam casting- ceramic casting
- Explain why processes such as sand, shell mold, ceramic and investment casting can produce parts with greater shape complexity than permanent-mold and centrifugal casting
- Why die casting can produce the smallest parts
- Why die casting is not usually used for high temperature materials?