Introduction

- Casting of Ingot and **Shape casting**
- Major Classification
  - Expandable Mold
    - A new mold is required for each new casting
    - Production rate is limited except Sand casting
    - Sand Casting, Shell Molding, Vacuum Molding, Expandable Polystyrene, Investment Casting, Plaster Molding, Ceramic Mold Casting
  - Permanent Mold
    - Mold is made of durable materials
    - Ideal for a product with a high production rate

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1. Sand Casting

- Most widely used casting process.
- Parts ranging in size from small to very large
- Production quantities from one to millions
- Sand mold is used.
- Patterns and Cores
  - Solid, Split, Match-plate and Cope-and-drag Patterns
  - Cores – achieve the internal surface of the part
- Molds
  - Sand with a mixture of water and bonding clay
  - Typical mix: 90% sand, 3% water, and 7% clay
  - to enhance strength and/or permeability

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Molds

- Sand – Refractory for high temperature
- Size and shape of **sand**
  - Small grain size -> better surface finish
  - Large grain size -> to allow escape of gases during pouring
  - Irregular grain shapes -> strengthen molds due to interlocking but to reduce permeability
- Types
  - *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

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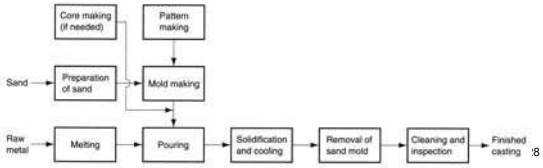
Steps in Sand Casting

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

- The mold must also contain gating and riser system
- For internal cavity, a *core* must be included in mold
- A new sand mold must be made for each part

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



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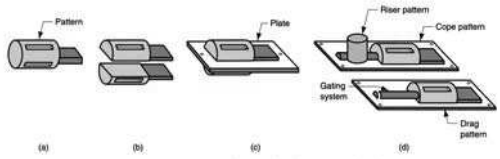
Types of patterns used in sand casting:



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

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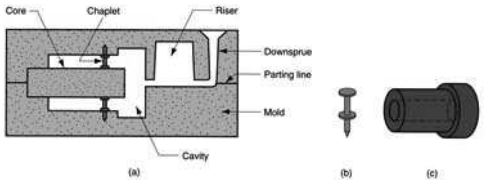
Internal Cavity with Core



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

(b) possible chaplet design

(c) casting with internal cavity

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Desirable Mold Properties and Characteristics

- 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?

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2. Other Expendable Mold Casting

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

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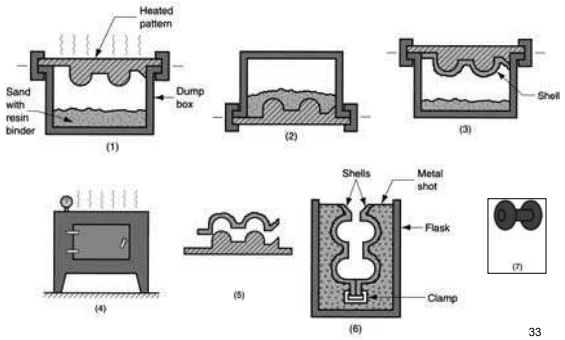
Steps in shell-molding



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Shell Molding

- Advantages:
  - Smoother cavity surface permits easier flow of molten metal and better surface finish on casting
  - Good dimensional accuracy
  - Machining often not required
  - Mold collapsibility usually avoids cracks in casting
  - Can be mechanized for mass production
- Disadvantages:
  - More expensive metal pattern
  - Difficult to justify for small quantities

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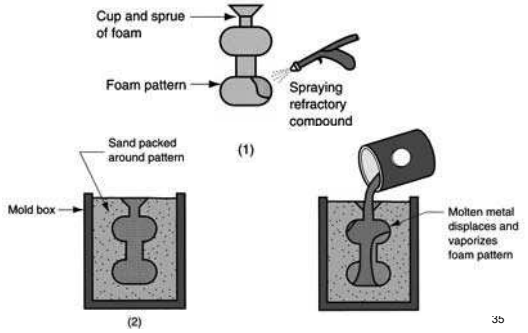
Expanded Polystyrene Casting



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Expanded Polystyrene Casting

- Advantages:
  - Pattern need not be removed from the mold
  - Simplifies and expedites mold-making, since two mold halves (cope and drag) are not required as in a conventional green-sand mold
  - Automated Mass production of castings for automobile engines
- Disadvantages:
  - A new pattern is needed for every casting
  - Economic justification of the process is highly dependent on cost of producing patterns

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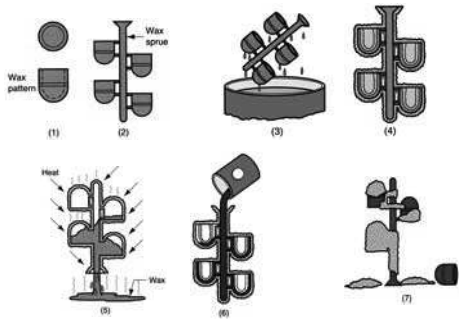
Investment Casting



Investment Casting

- Advantages:
  - 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 Molding

- Similar to sand casting except mold is made of plaster of Paris (gypsum - $CaSO_4 \cdot 2H_2O$)
- Plaster and water mixture is poured over plastic or metal pattern to make a mold
- Advantages:
  - Good dimensional accuracy and surface finish
  - Capability to make thin cross-sections in casting
- Disadvantages:
  - Moisture in plaster mold causes problems:
    - *Mold must be baked to remove moisture*
    - *Mold strength is lost when is over-baked, yet moisture content can cause defects in product*
  - Plaster molds cannot stand high temperatures

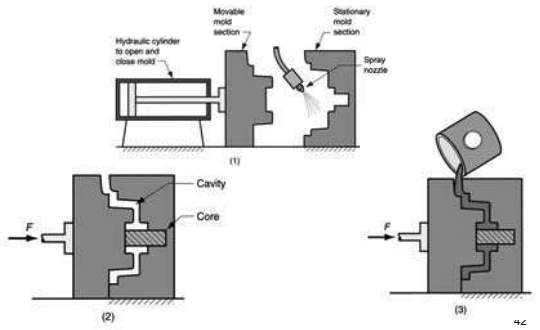
3. Permanent Mold Casting

- Basic Permanent Mold Process
  - Uses a metal mold constructed of two sections designed for easy, precise opening and closing
  - Molds for lower melting point alloys: steel or cast iron and Molds for steel: refractory material, due to the very high pouring temperatures
- Variations
  - Slush Casting
  - Low-pressure Casting
  - Vacuum Permanent Mold Casting
- Die Casting
- Centrifugal Casting

Permanent Mold Casting Process

- Metals - Al, Mg, Copper alloy and Cast Iron
- Basic Steps
  - Preheated Mold (metals to flow)
  - Coatings are sprayed
  - Pour and solidify
  - Mold is open and casting is removed
- Advantage - Good surface finish and dimensional control and Fine grain due to rapid solidification.
- Disadvantage - Simple geometric part, expensive mold.
- Example - automobile piston, pump bodies castings for aircraft and missiles.

Basic Permanent Mold Process



Permanent Mold Casting

- Advantages:
  - Good dimensional control and surface finish
  - More rapid solidification caused by the cold metal mold results in a finer grain structure, so stronger castings are produced
- Limitations:
  - Generally limited to metals of lower melting point
  - Simple part geometries compared to sand casting because of the need to open the mold
  - High cost of mold
- Due to high mold cost, process is best suited to automated high volume production

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Die Casting

- The molten metal is injected into mold cavity (die) under **high pressure** (7-350MPa). Pressure maintained during solidification.
- Hot Chamber (Pressure of 7 to 35MPa)
  - The injection system is submerged under the molten metals (low melting point metals such as lead, zinc, tin and magnesium)
- Cold Chamber (Pressure of 14 to 140MPa)
  - External melting container (in addition aluminum, brass and magnesium)

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Die Casting

- Molds are made of tool steel, mold steel, maraging steel, tungsten and molybdenum.
- Single or multiple cavity
- Lubricants and Ejector pins to free the parts
- Venting holes and passageways in die
- Formation of flash that needs to be trimmed
- Advantages
  - High production, Economical, close tolerance, good surface finish, thin sections, rapid cooling

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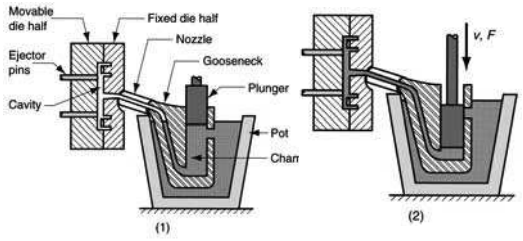
Hot-Chamber Die Casting



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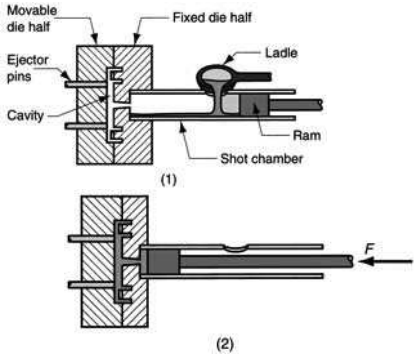
Cold Chamber Die Casting



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Die Casting

- Advantages:
  - Economical for large production quantities
  - Good dimensional accuracy and surface finish
  - Thin sections are possible
  - Rapid cooling provides small grain size and good strength to casting
- Disadvantages:
  - Generally limited to metals with low metal points
  - Part geometry must allow removal from die cavity

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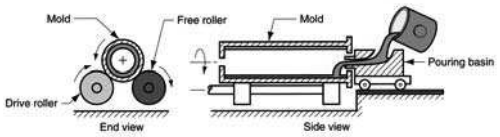
Centrifugal casting

- True centrifugal casting
- Semicentrifugal casting
- Centrifuge casting



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4. Foundry Practice

- Furnace
  - Cupolas (Fig. 11.18)
  - Direct Fuel-fired furnace
  - Crucible Furnace (Fig. 11.19)
  - Electric-arc Furnace
  - Induction Furnace
- Pouring with ladle
- Solidification – watch for oxidation
- Trimming, surface cleaning, repair and heat treat, inspection

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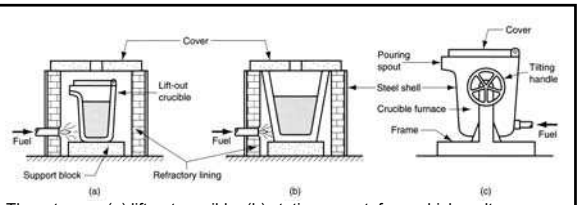
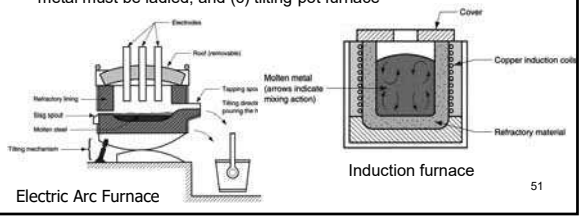


Three types : (a) lift-out crucible, (b) stationary pot, from which molten metal must be ladled, and (c) tilting-pot furnace



Electric Arc Furnace

Induction furnace

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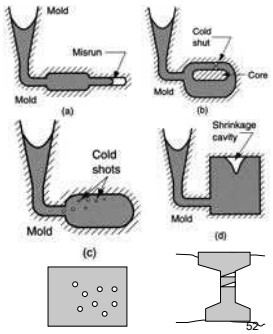
5. Casting Quality

- Casting defects
  a) Misruns
  b) Cold shut
  c) Cold shots
  d) Shrinkage cavity
  e) Microporosity
  f) Hot Tearing



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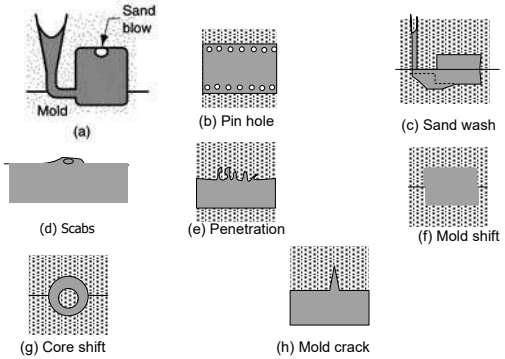
Sand Mold defects



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6. Metals for Casting

- Ferrous casting alloys: cast iron
  - Gray Cast Iron, Nodular iron, White Cast Iron, Malleable Iron, Alloy cast iron
- Ferrous casting alloys: Steels
  - Melting temperature is higher that casting alloys. Thus they are more reactive.
  - Less Fluidity
  - Higher strength, Tougher
  - Isotropy and weldable
- Nonferrous casting alloys
  - Aluminum, Magnesium, Copper, Tin-based, Zinc, Nickel and Titanium Alloys

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