CHAPTER 11
PART I
Metal Casting Processes
Topics

• Introduction
• Sand casting
• Shell-Mold Casting
• Expendable Pattern Casting
• Plaster-Mold Casting
Introduction

- Metal-Casting Processes
  - First casting were made during 4000 – 3000 BC
  - In time many casting processes have been developed
  - Many parts can be made from castings
    - Engine blocks
    - Cameras
    - Gun barrels
    - Cook ware
    - Etc
Fig 11.1 (a) The Polaroid PDC-2000 digital camera with AZ91D die-cast, high purity magnesium case. (b) Two-piece Polaroid camera case made by the hot-chamber die casting process
# General Characteristics of Casting Processes

## Table 11.2

<table>
<thead>
<tr>
<th>Process</th>
<th>Typical materials cast</th>
<th>Weight (kg)</th>
<th>Typical surface finish (μm, Rₐ)</th>
<th>Porosity*</th>
<th>Shape complexity*</th>
<th>Dimensional accuracy*</th>
<th>Section thickness (mm)</th>
<th>Knurl (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>All</td>
<td>Minimum: 0.05, Maximum: no limit</td>
<td>5-25</td>
<td>4</td>
<td>1-2</td>
<td>3</td>
<td>3</td>
<td>No limit</td>
</tr>
<tr>
<td>Shell</td>
<td>All</td>
<td>Minimum: 0.05, Maximum: 100+</td>
<td>1-3</td>
<td>4</td>
<td>2-3</td>
<td>2</td>
<td>2</td>
<td>--</td>
</tr>
<tr>
<td>Expendable mold pattern</td>
<td>All</td>
<td>Minimum: 0.05, Maximum: no limit</td>
<td>5-20</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>No limit</td>
</tr>
<tr>
<td>Plaster mold</td>
<td>Nonferrous (Al, Mg, Zn, Cu)</td>
<td>Minimum: 0.05, Maximum: 50+</td>
<td>1-2</td>
<td>3</td>
<td>1-2</td>
<td>2</td>
<td>1</td>
<td>--</td>
</tr>
<tr>
<td>Investment</td>
<td>All (High melting pt.)</td>
<td>Minimum: 0.005, Maximum: 100+</td>
<td>1-3</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>75</td>
</tr>
<tr>
<td>Permanent mold</td>
<td>All</td>
<td>Minimum: 0.5, Maximum: 300</td>
<td>2-3</td>
<td>2-3</td>
<td>3-4</td>
<td>1</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>Die</td>
<td>Nonferrous (Al, Mg, Zn, Cu)</td>
<td>Minimum: &lt;0.05, Maximum: 50</td>
<td>1-2</td>
<td>1-2</td>
<td>3-4</td>
<td>1</td>
<td>0.5</td>
<td>12</td>
</tr>
<tr>
<td>Centrifugal</td>
<td>All</td>
<td>Minimum: --, Maximum: 5000+</td>
<td>2-10</td>
<td>1-2</td>
<td>3-4</td>
<td>3</td>
<td>2</td>
<td>100</td>
</tr>
</tbody>
</table>

*Relative rating: 1 best, 5 worst.

**Note:** These ratings are only general; significant variations can occur, depending on the methods used.
Trends – impacting industry

- Continuing mechanization & automation of the casting process
- Increasing demand for high-quality castings

Ex: Typical gray-iron castings used in automobiles
Types of Molds

• **Expandable molds** – mixed with various types of binders or bonding agents
  – Sand
  – Plaster
  – Ceramics
• *Note: these molds are able to withstand high temperatures and mold is broken up to remove the casting*

• **Permanent molds** - Made of metal
  • Subjected to a higher cooling rate
  • Affects grain size
  – Used repeatedly
  – Casting can be removed easily

• **Composite molds** - Made of two or more materials
  • Sand
  • Graphite
  • Metal
  – Combines advantages of each material
  – Used to:
    • Control cooling rates
    • Improve mold strength
    • Optimize economics of the process
Sand Casting

Traditional way to cast metals

- How to make a sand casting
  - Placing a pattern having the shape of the desired casting in to the sand to make an imprint
  - Incorporating a gating system
  - Filling the resulting cavity with molten metal
  - Allow the metal to cool
  - Break away the sand mold

Type of sand to use

- Most common – silica sand (SiO$_2$)
- There are two types of sand:
  - Naturally bonded (bank sand)
  - Synthetic (lake sand)
    - Preferred by foundries b/c its composition can be controlled
Steps in Sand Casting

Furnaces  Solidification  Shakeout  Additional heat treatment  Defects

Pattern making  Core making  Removal of risers  treatment  Pressure
gating systems  tightness  and gates
Schematic illustration of sand mold features
Sand Casting Con’t

• **Selection of sand**
  – Fine round grains
    • Smooth surface finishes
    • Can be closely packed
    • Have lower mold permeability
    • Enhances mold strength
  – Course grains
    • Allow gases and steam escape

• **Sand molds**
  – Should have good collapsibility
  – Sand should be mixed thoroughly with
    • Clay (bentonite) – cohesive agent
    • Zircon, olivine, and iron silicate sands are used in steel foundries for low thermal expansion
    • Chromites is used for its high heat transfer characteristics

• **Types of sand molds**
  – Green mold sanding
    • Mixture of sand, clay, and water
    • “green” – sand in the mold is moist
    • Least expensive method of making molds
Sand Casting Con’t

Skin-dried molds
- Mold surfaces are dried
- Used for large castings
- Have higher strength than **green-sand molds**
- Better dimensional accuracy and surface finish
- Drawbacks:
  - Distortion to the mold is greater
  - Castings susceptible to hot tearing
  - Slower production rate

Cold-box molds
- Various organic and inorganic binders are blended into the sand for greater strength
- Dimensionally more accurate

No-bake mold
- Synthetic liquid resin is mixed into the sand
- Hardens at room temperature
Sand Casting Con’t

• Major components of sand molds:

  Flask – supports the mold
  Pouring basin – in which molten metal is poured in to
  Sprue – through which molten metal flows downward
  Runner system – channels that carry molten metal from
                  the sprue
  Risers - supply additional metal to the casting during
          shrinkage.

Cores
  • Inserts made of sand
  • Used to make hollow regions
  • Used to form letterings on the casting and other features

Vents – used to carry off gases that are produced and
         exhaust air from the mold cavity as metal flows on to
         the mold
• **Patterns**
  – Used to mold the sand mixture
  – Made from
    • Wood
    • Plastic
    • Metal
  – They must be tough enough to be used repeatedly
  – Made of different materials to reduce wear
  – Coated with a parting agent to facilitate their removal
  – Patterns
    • One-piece patterns – for simple low cost production
    • Split patterns – each part forms a portion of the cavity
    • Match-plate patterns – popular type of pattern
      – Two-piece patterns are constructed by securing each half of one or more split patterns to the opposite sides of a single plate
      – Used in large production runs and in molding machines
  – Rapid prototyping
    • Used to make a mold quickly
    • Reduces cost
Patterns

Typical metal match-plate pattern used in sand casting

Taper in patterns for ease of removal from the sand mold
**Cores** – made of sand aggregates

- Possess:
  - Strength
  - Permeability
  - Ability to withstand heat
  - Collapsibility
- Anchored by core points
- Chaplets are used to keep the core from moving
Sand molding machines:
- Vertical flaskless molding
- Sandslinger
- Impact molding
- Vacuum molding

• The sand-casting operation
Shell-Mold Casting

- Developed in the 1940’s
- Produces close dimensional tolerances
- Good surface finish
- Low cost process

Common methods of making shell molds.
(a) Pattern rotated and clamped
(b) Pattern and dump box rotated
(c) Pattern dump box in position for the investment
(d) Pattern and shell removed from dump box
Composite Molds

- Made up of two or more different materials
- Used in shell molding
- Used in casting complex shapes

(a) Schematic illustration of a semi permanent composite mold. (b) A composite mold used in casting an aluminum-alloy
**Sodium silicate process**

- Mixture of sand and 1.5% - 2% sodium silicate
- The mixture is packed around the pattern
- Harden by blowing CO$_2$ gas though it
- First used in the 1950’s
- Reduces tendency for parts to tear

**Rammed Graphite Molding**

- Rammed graphite is used to make molds for:
  - Titanium
  - Zirconium
- Sand cannot be used because sand will react vigorously with silica
- Molds are packed like sand molds
- Air dried
- Baked at 175 C
- Stored under controlled humidity and temperature
- Casting process similar to those for sand molds
• Polystyrene beads are placed in a preheated die
• The polystyrene bead expand to fix the die
• The die is cooled and the polystyrene pattern is removed
• The polystyrene pattern is placed in a mold with support sand
• The polystyrene pattern evaporates with contact of molten metal to form a cavity

Expendable-Pattern Casting

Schematic illustration of the expendable pattern casting process also known as lost foam or evaporative casting.
Plaster-Mold Casting

- Mold is made of plaster
- Mixed with water and additives and poured over a pattern
- After plaster sets, pattern is removed and the mold is dried at 120°C
- Have low permeability – gases cannot escape
- Patterns are made of:
  - Al alloys,
  - Thermosetting plastics
  - Brass or Zinc alloys
- Have fine details and good surface finish
- Form of *precision casting*
Ceramic-Mold Casting

- Similar to *plaster-mold process*
- Uses refractory mold materials
- Suitable for high temperature applications

- Mixture made of:
  - Fine grained zircon
  - Aluminum oxide
  - Silica

- Mixture is mixed with bonding agents and poured over pattern

- Molds are baked in an oven
- Molds can be used to cast high-temperature alloys
- Castings have good surface finishes
- Good dimensional accuracy
- Some what expensive to make
THE END