Chapter 13
Multiple-Use Casting Processes

Before you begin: Turn on the sound on your computer. There is audio to accompany this presentation.
Background

- In Chapter 12, all of the processes were considered to be expendable mold.
- After each pour, the mold was destroyed to retrieve the casting.
- To create a new casting, a new mold must be made.
- This takes time, effort, and money.
- For higher production runs, those processes may not be suitable – let’s look at permanent mold processes.

Multiple Use Mold Casting

- Multiple use mold casting processes overcome most of the expendable mold limitations.
- However, multiple use mold also has limitations.
- Since molds are generally made of metal:
  - Limited to lower-melting temperature materials.
  - Part size often limited.
  - Dies and molds can be costly.

Multiple Use Mold Processes

- Permanent Mold
- Die Casting
- Squeeze Casting
- Semisolid Casting
- Centrifugal Casting
- Continuous Casting
Multiple Use Mold Casting

- In these cases a reusable mold is created from materials such as gray iron, steel, graphite, bronze etc.
- Mold is made in segments which can be hinged to permit removal of the casting.
- Typical alloys cast with these processes are:
  - Aluminum
  - Zinc
  - Magnesium
  - Lead
  - Some copper based alloys

Permanent Mold Casting

Figure 13-1 Truck and car pistons are mass-produced by the millions using permanent-mold casting.

Permanent Mold Casting

Piston produced by permanent-mold casting.
Advantages

- Mold is reusable.
- Surface finish and dimensional tolerances are better than sand casting.
- Directional solidification and faster cooling rates possible mold cooling:
  - Faster cooling rates and yield stronger castings.
- Can incorporate permanent or dry-sand cores for internal geometries:
  - Dry-sand core process is known as semi-permanent mold casting.

Disadvantages

- Usually limited to lower melting point metals – the higher the temperature.
- High tooling costs for the molds – high volume required to justify the cost.
- Mold complexity is often restricted because the rigid container offers no collapsibility.
- Molds are not permeable – venting required which can be problematic.

Multiple Use Mold Processes

- Permanent Mold
- Die Casting
- Squeeze Casting
- Semisolid Casting
- Centrifugal Casting
- Continuous Casting
- Gravity Die Casting (aka Gravity Fill)
- Slush Casting
- Low Pressure Permanent Mold (LPPM)
- Vacuum Permanent Mold
Gravity Fill Process

- Uses pouring techniques similar to sand casting where gravity pushes the metal into the mold cavity.
- Primary difference is in the mold material – metal.
- Has all the same components in the gating system as sand casting (including risers).
- Tilt-Pour variation → metal poured into pouring basin, mold then rotates to cause flow into mold cavity. Process minimizes turbulence.

Example of the gravity fill process.

Examples of gravity fill casting dies.
Slush Casting

- Used to create hollow castings.
- Same process as gravity fill permanent mold – just variation in time.
- Since molten metal freezes from mold wall inward, it is possible to only allow a thin shell (of desired thickness) of the casting to solidify and the rest of the molten metal can then be poured back out of the mold.
- Used for decorative objects and statues.

Low Pressure Permanent Mold

- Used to avoid some of the defect problems associated with molten metals in contact with the atmosphere.
- Low pressures are used to force molten metal into the mold cavity (3-15 psi).
- Molten metal never touches atmosphere and so castings are extremely clean and slow filling process eliminates turbulence of gravity fill (also prone to absorbing gases).
- Continuous pressure feeding molten metal into mold and solidification from top down eliminates the need for risers.

Low Pressure Permanent Mold

- Typical LPPM Materials:
  - Aluminum
  - Magnesium
  - Some copper-alloys
Vacuum Permanent Mold

- Another variation of permanent mold process.
- This time a vacuum is used to get metal to fill into mold cavity rather than forcing with pressure.
- Has same benefits as low pressure permanent mold process but mechanical properties are better.
- Produces thin-walled casting with excellent surface finish.

![Figure 13-3 Schematic illustration of vacuum permanent-mold casting. Note the similarities with LPPM process.](image)

Multiple Use Mold Processes

- Permanent Mold
- Die Casting
- Squeeze Casting
- Semisolid Casting
- Centrifugal Casting
- Continuous Casting

- Hot Chamber Machines
- Cold Chamber Machines
Die Casting

- In die casting – molten metal is forced into metal molds under very high pressures and held under pressure during solidification.
- Pressures are several thousand psi.
- Fine detail and excellent surface finish can be achieved.
- Most die castings are made from aluminum, zinc, and copper.

![Figure 13-4 Various types of die-casting dies.](image1)

Die Casting – Dies

Die Casting – Casting Examples

![Die Casting Examples](image2)
Advantages

- High production rates.
- Products have good strength.
- Shapes can be quite intricate.
- Surface finish – very good.
- Dimensional tolerance – very good.
- Virtually no finish machining required.
- Risers are not needed.
- Many parts can be made at one time.

Disadvantages

- Typically limited to low melting point metals.
- Equipment is very expensive.
- Molds are very expensive – hardened tool steels.
- Limited to relatively small parts – 20 lb and 24 in max.
- Die life is dependent on metal being poured – higher temps = shorter life.
- High pressure introduce turbulence to molten metal and can cause porosity.
- Sand cores cannot be used due to high pressures.

Hot Chamber Machines

- Also known as gooseneck machine.
- The plunger used to force molten metal into the mold cavity (die set) is submerged in a chamber of molten metal.
- Can only be used for lowest melting point metals (zinc, tin, lead, etc.)
- No handling or transfer of molten metal.
- Fast cycling times (up to 15 cycles/min).
Hot Chamber Machines

Figure 13-5 Principle components of a hot-chamber die-casting machine.

Cold Chamber Machines

- Used for materials not suitable for hot chamber – aluminum, magnesium, copper, and high aluminum zinc alloy.
- Metal is melted in separate furnace and transported to die casting machine.
- Measured quantity is fed into shot chamber.
- Pressure maintained or increased during solidification.
Porosity and Venting

- Due to rapid filling time, it is often very difficult to remove air from mold and this causes porosity problems.
- Venting is also very difficult due to high pressures.
- Very thin vents are typically placed along split line.
- Air must escape before metal fills and freezes in vents.
- Flash from vents is trimmed after removal.
Multiple Use Mold Processes

- Permanent Mold
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Squeeze and Semisolid Casting

- Variation of high pressure die casting.
- Advantages:
  - High production.
  - Good surface finish and dimensional precision.
  - Near net-shape with thin cross sections.
- Materials:
  - Alloys of aluminum primarily.
  - Also magnesium, zinc, copper and a limited number of ferrous alloys.

Squeeze Casting

- Squeeze casting uses mold designs with larger gates and slower fill velocities to avoid turbulence.
- Once filled, pressures are increased to a range of 3,000-25,000 psi during solidification.
- Solidification direction and gate design must allow gates to freeze last to allow pressurized runner to feed metal to compensate for shrinkage.
- Results – intricate shapes with reduced gas and shrinkage porosity and enhanced mechanical properties.
Squeeze Casting

Semi-Solid Casting

- For metals with freezing range (mushy zone) where some material is liquid and some is solid.
  - Slurry contains ~30% solid material.
- Rheocasting – molten metal cooled to semisolid state with constant stirring.
- Thixotropic material – can be handled as solid, but flows as liquid with stirring or pressure.
  - Variation of process uses granules or pellets.

Semi-Solid Casting

- Process is characterized by:
  - Low turbulence resulting in less entrapment and porosity.
  - Lower injection temperatures.
  - Quick solidification time (material is already partially solid).
  - High quality intricate parts with good finish.
Multiple Use Mold Processes

- Permanent Mold
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Centrifugal Casting

- Uses inertial forces of rotation or spinning to distribute the molten metal into the mold cavity.
- Products include hollow cylindrical shapes such as pipe, pressure vessels, brake drums and rings.
- Capability:
  - Diameter: 3 to 55 in.
  - Wall Thickness: up to 10 in.
  - Length: up to 40 ft.
**True Centrifugal Casting**

- Forms hollow castings by flinging molten metal about either a horizontal or vertical axis.
- Speeds of 300 – 3000 rpm are typical.
- No need for risers.
- Most shapes are round, but other symmetrical shapes can be formed.
- Vertical orientation must also take gravitational forces into effect.

**Semi-Centrifugal Casting**

- In this case, centrifugal force assists the flow of molten metal from a central reservoir to the extremities of a rotating symmetrical mold.
- Central reservoir acts as a riser during solidification.
- Rotation speed slower than in true centrifugal casting.
Centrifuging

- Also known as spin casting.
- Uses central reservoir similar to “semi” case.
- In this type, mold contains gates and runners for several molds and centrifugal force is used to forces metal through those runners to supply the various castings.
- Relatively low speeds can be used.
- Used with rubber molds and low temperature alloys to make small products with close tolerances and excellent detail.

Figure 13-12 Schematic of a centrifuging process. Metal is poured into the central pouring sprue and spun into the various mold cavities.

Multiple Use Mold Processes

- Permanent Mold
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Continuous Casting

- Typically used to produce basic shapes as feedstock for rolling and forging processes.
- Can be used to produce long lengths of specialized product.

Other Aspects of Casting

- Furnaces
- Melting
- Pouring
- Cleaning
Melting and Pouring

- All casting processes begin with molten metal.
- Melting furnaces should be capable of holding molten metal for extended periods of time without degradation of quality.
- Melting furnaces should be economical to operate.
- Furnace feedstock may consist of ingots and scrap along with recycled sprues, runners and gates.
- Some type of pouring device is required to transfer the molten metal to the molds.

Melting Furnace Types

- Cupolas – refractory lined, vertical steel shell. Operation similar to blast furnace.

- Indirect Fuel-Fired (aka Crucible) – crucible is heated by an external flame.
Melting Furnace Types

- **Direct Fuel-Fired** (aka Reverberatory) — similar to open hearth furnaces with flame passing directly over pool of molten metal.

  ![Cross section of a direct fuel-fired furnace.](image1)

  Hot combustion gases pass across the surface of a molten metal pool.

- **Arc** — uses electrodes create an arc between the electrode and charge.

  ![Schematic diagram of an electric-arc furnace.](image2)

  ![Electric-arc furnace, tilted for pouring.](image3)

- **Induction** — low or high-frequency current passes through coil surrounding the crucible.

  ![Schematic showing the basic components of a coreless (high-frequency) induction furnace.](image4)

  ![Cross section showing the principle of the low-frequency or channel-type induction furnace.](image5)
Melting
- Selection of melting method depends on:
  - Temperature and superheat requirements.
  - Variety of alloys and feedstock form.
  - Melting rate.
  - Desired quantity of molten metal.
  - Desired quality of the molten metal.
  - Availability and cost of fuel/energy.
  - Batch or continuous operation.
  - Emission control.
  - Capital and operating cost.

Holding Furnace
- Sometimes used between the melting furnace and pouring step.
- Holds liquid metal at desired pouring temperature.

Pouring
- Pouring ladle properties:
  - Maintain molten metal temperature.
  - Ensure only quality metal introduced into the mold.
- Variations:
  - Handheld, shank-type ladle.
  - Bottom-pour ladle.
  - Teapot-type ladle.
Cleaning and Finishing

- Cleaning includes removing cores, gates, risers and flash from casting.
- Surface must be cleaned to remove sand and oxidation.
- Finishing includes repairing defects:
  - Grinding and welding of cracks, voids and laps.
  - Impregnation of resins for porosity.
  - Infiltration of lower melting temperature metal.

Cleaning and Finishing

- Finishing may include heat treatment:
  - Anneal of steel castings to reduce hardness and internal stresses.
  - Non-ferrous castings heat treated to provide chemical homogeneity and stress relief.
- Inspection techniques include most NDT:
  - Radiography – X-ray and gamma ray.
  - Liquid Penetrant – surface defects.
  - Magnetic Particle – ferromagnetic material only.

Casting Process Selection

Unit cost is a key consideration in the selection of a casting process.

High initial cost due to tooling (die) cost.

Figure 13-20 Typical unit cost of castings comparing sand casting and die casting.
### Casting Process Selection

#### Table 13.6: Comparison of Casting Processes

<table>
<thead>
<tr>
<th>Process or Characteristic</th>
<th>Greensand Casting</th>
<th>Chemically Bonded Sand (Chill/Chill-Off)</th>
<th>Ceramic Molding</th>
<th>Permanent-Mold Casting</th>
<th>Die Casting</th>
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<tbody>
<tr>
<td>Initial cost to start up</td>
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<tr>
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<td>0.005–0.002</td>
<td>0.005–0.002</td>
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#### The End – See Oncourse for Videos