ME 330
Manufacturing Processes

CASTING PROCESSES (cont.)
Casting

- Principle of the process
- Structure/configuration
- Process modeling
- Defects
- Design For Manufacturing (DFM)
- Process variation
Casting process classification:

In terms of mold:

1. Expendable (mold is destroyed for each casting)
2. Permanent (mold is used for many castings)

Expendable casting: sand, investment, and so on

Permanent casting: die casting, and so on
Process variation lies in the variation of the principle of the process

How mold cavity is made
Melt the pattern and evaporate it
Other **Expendable** Mold Processes (excluding sand casting)

- Shell Molding.
- Vacuum Molding.
- **Lost-Foam Process**.
- Investment Casting.
- Plaster Mold and Ceramic Mold Casting.
Lost-Foam Process

- Similar to the sand casting process, but instead of using a removable/reusable pattern to make the mold cavity, an expendable polystyrene foam pattern is used.
- How it works: to use a mold of sand packed around the foam pattern which vaporizes when molten metal is poured into mold.
- Foam pattern includes sprue, riser, gating system, and internal cores (if needed).
Steps in Lost-Foam Process

Polystyrene foam pattern is coated with refractory compound.
Steps in Lost-Foam Process

Foam pattern is placed in mold box, and sand is compacted around the pattern.
Steps in Lost-Foam Process

Molten metal is poured into the portion of the pattern that forms the pouring cup and sprue.

Molten metal displaces and vaporizes foam pattern.
Lost-Foam Process

Applications:

Mass production of castings for automobile engines
Lost-Foam Process: Advantages and Disadvantages

- Advantages of expanded polystyrene process:
  1. Pattern is not removed from the mold
     Can have more complex shapes & no need for parting line
  2. Simplifies and speeds mold-making, because two mold halves are not required as in a conventional green-sand mold

- Disadvantages:
  1. A new pattern is needed for every casting
  2. Process is highly dependent on cost of producing patterns
Investment Casting
(a.k.a. Lost Wax Process)

- A pattern made of wax is coated with a refractory material to make the 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.
Steps in Investment Casting

- Wax patterns are produced.
- Several patterns are attached to a sprue to form a pattern tree.
Steps in Investment Casting

- Pattern tree is coated with a thin layer of refractory material.
- Full mold is formed by covering the coated tree with sufficient refractory material to make it rigid.
Steps in Investment Casting

- Mold is held in an inverted position and heated to melt the wax and permit it to drip out of the cavity.

- Mold is preheated to a high temperature, the molten metal is poured, and it solidifies.
Steps in Investment Casting

- Mold is broken away from the finished casting and the parts are separated from the sprue.
Investment Casting

Typical Applications:

- Turbines
- Example: One-piece compressor stator made by investment casting (photo courtesy of Howmet Corp.)
Investment Casting: Advantages and Disadvantages

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

- **Disadvantages:**
  - Many processing steps are required
  - Relatively expensive process
Permanent Mold Casting Processes
Permanent Mold: Casting Processes

- Economic disadvantage of expendable mold casting:
  - A new mold is required for every casting

- In permanent mold castings, the mold is reused many times – great for mass production

- The processes include:
  - Basic permanent mold casting
  - Die casting
  - Centrifugal casting
The Basic Permanent Mold Process

- Uses a metal mold constructed of two sections designed for easy, precise opening and closing.
- Molds used for casting lower melting point alloys are commonly made of steel or cast iron.
- Molds used for casting steel must be made of refractory material, due to the very high pouring temperatures.
Steps in Basic Permanent Mold Casting

- Mold is preheated and coated for lubrication and heat dissipation
Steps in Basic Permanent Mold Casting

- Cores (if any are used) are inserted and mold is closed
Steps in Basic Permanent Mold Casting

- Molten metal is poured into the mold, where it solidifies.
Basic Permanent Mold Casting: Advantages

Advantages of permanent mold casting:

1. Good dimensional control and surface finish.

2. Rapid solidification caused by metal mold results in a finer grain structure, so castings are stronger.

3. Economical for large production quantities & process can be automated.
Basic Permanent Mold Casting: Limitations

- Limitations:
  - Generally limited to metals of lower melting point
    - Not suited well for steel
  - Simpler part geometries compared to sand casting because of need to open the mold
  - Can only pour parts without thin sections because molten metal is gravity fed
  - High cost of mold, but generally lower than a die casting
Die Casting

- A permanent mold casting process in which molten metal is injected into mold cavity under high pressure.
- Mold cavity is made by 2 mold halves (called *dies*) that are closed together.
- Use of high pressure to force metal into die cavity is what distinguishes this from other permanent mold processes.
- Pressure is maintained during solidification, then mold is opened and part is removed.
Die Casting Machines

- Two main types:
  1. Hot-chamber machine
  2. Cold-chamber machine
Hot-Chamber Die Casting

Metal is melted in a container, and a piston injects liquid metal under high pressure into the die

- High production rates
  - 500 parts per hour not uncommon
- Applications limited to low melting-point metals that do not chemically attack plunger and other mechanical components
- Casting metals: zinc, tin, lead, and magnesium
  - Not aluminum because it chemically attacks
Hot-Chamber Die Casting

Hot-chamber die casting cycle:

- With die closed and plunger withdrawn, molten metal flows into the chamber.
Hot-Chamber Die Casting

- Plunger forces metal to flow into die, maintaining pressure during cooling and solidification.
Hot-Chamber Die Casting

- Plunger is withdrawn, die is opened, and casting is ejected
Cold-Chamber Die Casting

- Molten metal is poured into unheated chamber from an external melting container, and a piston injects metal under high pressure into die cavity.
- High production but not usually as fast as hot-chamber machines because of pouring step.
- Casting metals: aluminum, brass, magnesium alloys, zinc, tin, and lead alloys.
Cold-Chamber Die Casting Cycle

- With die closed and ram withdrawn, molten metal is poured into the chamber
Cold-Chamber Die Casting Cycle

- Ram forces metal to flow into die, maintaining pressure during cooling and solidification
Cold-Chamber Die Casting Cycle

- Ram is withdrawn, die is opened, and part is ejected
Molds for Die Casting

- Usually made of tool steel, mold steel, or mar-aging steel used to cast low melting point metal alloys.
- Tungsten and molybdenum (good refractory qualities) used to die cast steel and cast iron.
- Ejector pins required to remove part from die when it opens.
- Lubricants must be sprayed onto cavity surfaces to prevent sticking.
Die Casting: Advantages and Limitations

 Advantages:

- Economical for large production quantities & process can be automated
- Good accuracy and surface finish
- Thin sections possible
- Rapid cooling (due to metal die) means good strength in casting

 Disadvantages:

- Generally limited to metals with low metal points
- Part geometry must allow removal from die
- High mold costs
Semi-Solid Metal Casting

- Family of net-shape and near net-shape processes performed on metal alloys at temperatures between liquidus and solidus.
- Thus, the alloy is a mixture of solid and molten metals during casting (mushy state).
  - To flow properly, the mixture must consist of solid metal globules in a liquid
  - Achieved by stirring the mixture to prevent dendrite formation
- Uses molds that are similar to die casting.
Semi-Solid Metal Casting

- Advantages
  - Complex part geometries
  - Thin part walls possible
  - Close tolerances
  - Zero or low porosity, resulting in high strength of the casting
- Materials typically include magnesium, zinc, and aluminum alloys