Die Casting: Total relative part cost

Different type of metal casting process
- Sand Casting
- Investment Casting
- Die casting
  - Process
  - Equipment
  - Materials
  - Design guides
- Die Casting: Total relative part cost

Casting

- Basic Process
  - Melt metal alloy
  - Pour into mold
  - Allow solidification
  - Remove from mold
- Advantages:
  - Many alloys
  - Complex shapes
- NOTE: not all alloys can be cast

Casting Processes

- Metal Casting Processes
  - Expendable Mold Casting
    - Sand Casting
    - Shell mold Casting
    - Investment Casting
    - Carbon Dioxide Mold Casting
  - Non-expendable Mold Casting
    - Permanent Mold Casting
    - Die Casting
    - Centrifugal Casting
Sand Casting

- Molten metal is poured into a mold cavity formed out of sand
  - Natural Sand
  - Synthetic Sand
- Pattern is an approximate duplicate of the real part
  - Typically made of wood, sometimes metal
Sand Casting

Advantages
- Castings can be up to several tons
- Least expensive casting process
- Can be used with most metals

Disadvantages
- Rough Surface Finish
- Large dimensional variation
- Usually require Secondary Machining
- Parts have internal porosity
- Low production volume

- Vents
- Gating system
  - Sprues
    - Holes through which molten metal is poured
  - Runners
    - Networks through which the metal flows in the mold
  - Gates
    - Areas where the metal enters the impression (part)
- Risers
  - Reservoirs of molten metal to ensure complete part filling
- Vents
  - Holes allowing escape of gasses from the melt

- Sand casting
Sand Casting

- Consideration
  - Metal Match Plates
    - Used for large production volume
    - Two halves are mounted to this
  - Runner Patterns
    - A pattern may be used to imprint the runner system (high volume)
    - System is made by hand (low volume)
- Cores
  - Use cores in the same way as in injection molding
- Drafts
  - Need draft angle to easily remove the pattern

Guidelines

- When uniform cross-sections cannot be maintained, then changes in cross-sections must be gradual.
- Avoid intersection ribs because they create regions of heavy cross-section

Investment Casting

- This process is one of the oldest manufacturing processes.
  - Used by Egyptians 5000 years ago to make gold jewelry
- Similar to Sand Casting
  - DIFFERENCE: pattern is made of wax (or foam)
    - lost foam/wax casting
- Low production volume (<10,000 parts)
- Typical pattern production is by molding wax
  - Thus, costly features (undercuts) are also costly in this process
It can be used to make parts that cannot be produced by normal manufacturing techniques.
- turbine blades
- airplane parts

Other Casting Methods

- Centrifugal Casting
  - Mold is rotating (horizontal or vertical)
  - Primarily symmetric (rotational) parts (pipes, tubes, bushings, etc)
  - Thinner ribs and features
  - Finer grain structure

- Carbon Dioxide Mold Casting
  - Replace the sand/clay mixture with sodium silicate/sand
  - CO₂ used to harden the mold
  - Higher tolerances

- Permanent Mold Casting
  - Similar to die casting
  - Gravity used instead of forced pressure
  - Tolerances and finishes poor

Permanent Mold Casting

- Gravity used instead of forced pressure
- Higher tolerances
- Replace the sand/clay mixture with sodium silicate/sand
Other Casting Methods

- **Plaster Mold Casting**
  - Coat a pattern with plaster
  - Allow to harden
  - Remove pattern
  - Fill with melt

- **Ceramic Casting**
  - Same as plaster, but ceramic slurry is used instead of plaster

- **Shell Mold Casting**
  - Heat a pattern
  - Cover with resin/sand
  - Creates an expendable shell mold
  - Finer tolerances than traditional sand casting, not as good as investment

Die Cast

- Die-casting is the process of forcing molten metal under high pressure (10-210MPa or 1,450-3,050 psi) into the cavities of reusable steel molds.

- **Costs**
  - High tooling cost
  - Low unit cost

- **Parts**
  - Complex geometry
  - Thin walls
  - High dimensional accuracy
  - Good surface finish (post machining can be totally eliminated)

Example

- **Metal:** Aluminum
- **Process:** Die Cast
- **Weight:** 20 lb
- **Size:** Large (outer 12X12)
- **Market:** Automotive
- **Description:** Rear Sub-frame
Example

Metal: Zinc
Process: Die Cast
Weight: xx
Size: Large (over 12X12)
Market: Automotive
Description: 1974 Pontiac radiator grill

Example

Metal: Aluminum
Process: Die Cast
Weight: 0.35 lb
Size: Medium (3X3 to 12X12)
Market: Sports/Recreation
Description: Pistol frame

Example

Metal: Aluminum
Process: Die Cast
Weight: 10.29 lb
Size: Large (over 12X12)
Market: Industrial/Commercial
Description: Impeller for Industrial and Commercial Blowers
ME 455/655
Casting

Example

Metal: Aluminum
Process: Die Cast
Weight: 5.2 lbs
Size: Very Small (1X1)
Market: Automotive
Description: Starter Switch Housing

Die Casting

Two types
- Cold chamber
  - The molten metal is ladled into the cold chamber for each shot
  - Less time exposure of the melt to the plunger walls
  - This is particularly useful for metals such as Aluminum, and Copper (and its alloys) that alloy easily with iron at the higher temperatures.
- Hot chamber
  - Melt is kept liquefied as injected
  - Requires low melting point, high fluidity and low resistant alloys (Zinc, tin, lead)

Typical Pressures
- Hot Chamber: ~14-28 MPa (~2-4 ksi)
- Cold Chamber: ~17-41 MPa (~2.5-6 ksi)

Die Cast ... Equipments

Mold + Machine

- Holding molten metal in the shape of the final casting
- Providing a path for the molten metal to reach the casting cavity
- Removing heat from the casting
- Ejecting the solidified casting

Note: Die-casting machines are rated based on their clamping forces (From 100 to 4,000 tons)

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Aluminum is cast at a temperature of 650 ºC (1200 ºF).

Most common materials for die casting include:
- Aluminum
- Copper
- Zinc

Aluminum is cast at a temperature of 650 ºC (1200 ºF).

Pure Aluminum is rarely cast due to high shrinkage, and susceptibility to hot cracking.

Additive Alloys | Effect
--- | ---
Silicon | Increases melt fluidity
| Decreases machinability
Copper | Increases hardness, reduces ductility
| Reduces corrosion resistance

Zinc alloys are used in making precision parts such as sprockets, gears, and connector housings.

Zinc is alloyed with Aluminum (4%), which adds strength.

The casting is done at a fairly low temperature of 425 ºC (800 ºF) so the part does not have to cool much before it can be ejected from the die.

It allows for a fast fill, fast cooling (and ejection) and a short cycle time.

Zinc alloys are used in making precision parts such as sprockets, gears, and connector housings.

Copper alloys are used in plumbing, electrical and marine applications where corrosion and wear resistance is important.

<table>
<thead>
<tr>
<th>Material</th>
<th>Silicon</th>
<th>Copper</th>
<th>Tensile Strength</th>
<th>Properties</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA 380 (UNS A03800)</td>
<td>8.5 %</td>
<td>3.5 %</td>
<td>324 (47)</td>
<td>Fairly easy to fill</td>
<td></td>
</tr>
<tr>
<td>AA 384 (UNS A03840)</td>
<td>11 %</td>
<td>4 %</td>
<td>332 (48)</td>
<td>Easy to fill Automotive engines</td>
<td></td>
</tr>
<tr>
<td>AA 386 (UNS A03860)</td>
<td>9.5 %</td>
<td>0.6 %</td>
<td>317 (46)</td>
<td>Good corrosion resistance Marine Environments</td>
<td></td>
</tr>
<tr>
<td>AA 390 (UNS A03900)</td>
<td>17 %</td>
<td>4.5 %</td>
<td>283 (41)</td>
<td>Good wear resistance</td>
<td></td>
</tr>
</tbody>
</table>

Zinc can be made to close tolerances and with thinner walls than Aluminum, due to its high melt fluidity.
Vacuum Die Casting

- Large castings tend to have greater porosity problems, due to entrapped air, and the melt solidifying before it gets to the furthest extremities of the die-cast cavity.
- The porosity problem can be somewhat overcome by vacuum die casting.

Guidelines

- Basic functions
  - Flow
  - Solidification
  - Ejection (either from permanent mold or by destroying mold)
- Design a part such that
  - Flow is smooth
  - Fill cavity evenly
  - Cooling should be rapid to reduce cycle time
  - Cooling should be rapid to reduce warpage
  - For ejection, keep tooling to a minimum

Guideline

- Define closure and parting surface
  - Seek advice (expert or automation)
- Avoid undercuts
  - Strategically place undercuts
- Even flow
  - Avoid sharp corners (corners should be radiused generously)
  - Avoid sudden thickness changes
  - Avoid large differences in wall thicknesses
- Cool Rapidly
  - Avoid thick walls and sections
- Uniform wall thickness
- Multiple gates may be required for even filling
  - Fusion lines (areas where flows between gate filling) will weaken region
Draft allowance should be provided to all for releasing the parts; these are typically 0.25° to 0.75° per side depending on the material.

<table>
<thead>
<tr>
<th>Material</th>
<th>Min. Thickness mm (in)</th>
<th>Min. Draft Angle (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum alloys</td>
<td>0.9 mm (0.035 in)</td>
<td>0.5</td>
</tr>
<tr>
<td>Zinc alloys</td>
<td>0.6 mm (0.025 in)</td>
<td>0.25</td>
</tr>
<tr>
<td>Copper alloys (Brass)</td>
<td>1.25 mm (0.050 in)</td>
<td>0.7</td>
</tr>
</tbody>
</table>