IE 309 Manufacturing Processes I
Metal Casting Processes

Dr. Adnan Kefal
Faculty of Engineering and Natural Sciences
Sabanci University
adnankefal@sabanciuniv.edu
**Metal Casting Processes**

Introduction of molten metal into a mold cavity where, upon solidification, the metal takes place the shape of the cavity.

Capable of producing intricate shapes in a single piece, with varying sizes, including those with internal cavities
- e.g., engine blocks, cylinder heads, transmission house, pistons, turbine disks; dental crows, jewelries, frying pans

All metals can be cast in, or nearly in, the final shape desired with minimal finishing operations needed.
Important Factors in Casting Operation

Solidification of metals and the accompanying shrinkage

Flow of the molten metal into mold cavity

Heat transfer during solidification and cooling of the metal in the mold

Mold material and its influence on the casting operations

Steps in casting seem simple:
• Melt the metal
• Pour it into a mold
• Let it freeze
Capabilities and Advantages of Casting

Advantages:

• Can create complex part geometries
• Can create both external and internal shapes
• Some casting processes are net shape; others are near net shape
• Can produce very large parts
• Some casting methods are suited to mass production

Disadvantages:

• Limitations on mechanical properties
• Poor dimensional accuracy and surface finish for some processes; e.g., sand casting
• Safety hazards to workers due to hot molten metals
• Environmental problems
Parts Made by Casting

Big parts: engine blocks and heads for automotive vehicles, wood burning stoves, machine frames, railway wheels, pipes, church bells, big statues, and pump housings

Small parts: dental crowns, jewelry, small statues, and frying pans

All varieties of metals can be cast, ferrous and nonferrous

Typical gray-iron castings used in automobiles, transmission valve body (left) and the hub rotor with disk-brake cylinder

A cast transmission housing

A two-piece Polaroid camera case made by the hot-chamber die-casting process
Solidification Processes

Starting work material is either a liquid or is in a highly plastic condition, and a part is created through solidification of the material.

Solidification processes can be classified according to engineering material processed:

- Metals
- Ceramics, specifically glasses
- Polymers and polymer matrix composites (PMCs)
Pure metals have clearly defined melting points

**Solidification takes place at a constant temperature**

Latent heat is given off during the isothermal solidification

Casting contracts as it cools due to
  - Contraction from a superheated state to solidification temperature
  - Cooling from solidification to room temperature
Different Types of Alloys

Solid solutions: A solution in which two or more elements are soluble in a solid state, forming a single homogenous material in which the alloying elements are uniformly distributed throughout the solid. **Solute:** minor element; **Solvent:** major element.

- Substitutional
  - Solute atom size ≈ solvent atom size
  - Solute atom replaces the solvent atom, e.g., brass (Zn in Cu)

- Interstitial
  - Solute atom << solvent atom
  - Solute atom occupies interstitial positions, e.g., steel

Intermetallic compounds: Complex structures in which solute atoms are present among solvent atoms in certain specific proportions, e.g., CuAl2
Alloys solidify over a range of temperatures

Solidification begins with the temperature of the molten metal drops below the liquidus and is completed when the temperature reaches the solidus

Between the liquidus and solidus temperature, the alloys is mushy or pasty, and the composition and state is determined by the alloy’s phase diagram
Phase Diagram

The lever

\[ \text{Percent of Solid} = \frac{C_S - C_L}{C_S - C_L} \]

\[ \text{Percent of Liquid} = \frac{C_S - C_O}{C_S - C_L} \]
Solidification of the Castings

Two steps: nucleation and growth

Nucleation

• Nuclei form when the temperature drops below liquidus temperature
• Homogenous nucreation
  ➤ Occur without the help of foreign agent

Heterogeneous nucleation

• With the help of foreign particles (mold particles, impurities, added nucleating materials)
Equiaxed vs columnar structure

To promote equiaxed grains

- Low pouring temperature
- Alloy inclusion
- Inoculants

Dentic Solidification
Texture in Casting and Solidification Patterns for Gray Cast Iron

(a) Minutes after pouring

(b) Minutes after pouring

0.05–0.10% C Steel

0.25–0.30% C Steel

0.55–0.60% C Steel

Sand mold

Chill mold

Sand mold

Chill mold

Sand mold

Chill mold

Sand mold

Chill mold

Sand mold

Chill mold

Sand mold

Chill mold
Effects of Cooling Rates

Slow cooling rates result in coarse dendritic structures with large spacing between dendrite arms.

For higher cooling rates the structure becomes finer with smaller dendrite arm spacing.

Smaller the grain size, the strength and ductility of the cast alloy increase, microporosity in the casting decreases, and tendency for casting to crack.
Heat Transfer

Temperature distribution

Solidification time

• Chvorinov’s Rule:

$$\text{Solidification time} = C \left( \frac{\text{Volume}}{\text{Surface Area}} \right)^n$$

n~2; C is mold constant

• Mold material
• Thermal property of casting materials
• Pouring temperature relative to Tm
Significance of Chvorinov's Rule

A casting with a higher volume-to-surface area ratio cools and solidifies more slowly than one with a lower ratio

- To feed molten metal to the main cavity, solidification time for riser must be greater than that for main casting

Since mold constants of riser and casting will be equal, design the riser to have a larger volume-to-area ratio so that the main casting solidifies first

- This minimizes the effects of shrinkage
Shrinkage

Contraction of the molten metal as it cools before solidification

Contraction during phase change from liquid to solid

Contraction of the solidified metal as its temperature drops to ambient temperature

<table>
<thead>
<tr>
<th></th>
<th>Contraction (%)</th>
<th>Expansion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>7.1</td>
<td>Bismuth</td>
</tr>
<tr>
<td>Zinc</td>
<td>6.5</td>
<td>Silicon</td>
</tr>
<tr>
<td>Al - 4.5% Cu</td>
<td>6.3</td>
<td>Gray iron</td>
</tr>
<tr>
<td>Gold</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>White iron</td>
<td>4-5.5</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>Brass (70-30)</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td>90% Cu - 10% Al</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Carbon steels</td>
<td>2.5-4</td>
<td></td>
</tr>
<tr>
<td>Al - 12% Si</td>
<td>3.8</td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>3.2</td>
<td></td>
</tr>
</tbody>
</table>
Casting Operations

Casting is usually performed in a foundry, which is a factory equipped for:

- Making molds
- Melting and handling molten metal
- Performing the casting process

**Diagram:**
- **Open Mold**
  - Cast metal
  - Downsprue
  - Runner
  - Flask
  - Mold

- **Closed Mold**
  - Pouring cup
  - Cast metal in cavity
  - Riser
  - Core
  - Cope
  - Parting line
  - Drag
The Mold in Casting

Contains cavity whose geometry determines part shape

- Actual size and shape of cavity must be slightly oversized to allow for shrinkage of metal during solidification and cooling
- Molds are made of a variety of materials, including sand, plaster, ceramic, and metal
Heating Metal & Pouring Molten Metal

Heating furnaces are used to heat the metal to molten temperature sufficient for casting

The heat required is the sum of:

- Heat to raise temperature to melting point
- Heat of fusion to convert from solid to liquid
- Heat to raise molten metal to desired temperature for pouring

For this step to be successful, metal must flow into all regions of the mold, most importantly the main cavity, before solidifying

Factors that determine success

- Pouring temperature
- Pouring rate
- Turbulence
Successful casting requires proper design; to ensure adequate fluid flow in the system.

Typical riser-gated casting

Risers serve as reservoirs, supplying molten metal to the casting as it shrinks during solidification.
Two Basic Principles of Fluid Flow

Bernoulli’s Theorem

- Based on the principle of the conservation of energy
- Relates pressure, velocity, elevation of fluid and frictional losses in a system

\[ h_1 + \frac{p_1}{\rho g} + \frac{v_1^2}{2g} = h_2 + \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + f \]

Mass Continuity

- Law of mass continuity states that
- Flow rate will decrease as the liquid moves through the system

\[ Q = A_1 v_1 = A_2 v_2 \]

- $Q$ = volume rate of flow
- $A$ = cross sectional area of the liquid stream
- $\nu$ = average velocity of the liquid in that cross section
Fluid Flow

Sprue Design

• Assuming the pressure at the top of the sprue is equal to the pressure at the bottom and frictionless,

• Moving downward from the top, the cross sectional area of the sprue must decrease

\[
\frac{A_1}{A_2} = \sqrt{\frac{h_2}{h_1}}
\]

• Velocity of the molten metal leaving the gate is obtained from

\[
v = c \sqrt{2gh}
\]

where

\[h = \text{distance from the sprue base to the liquid metal height}\]

\[c = \text{friction factor}\]

For frictionless flow, \(c\) equals unity 1
Flows with friction \(c\) is always between 0 and 1
Flow Characteristics

Presence of turbulence is as opposed to the laminar flow of fluids

The Reynolds number, \( \text{Re} \), is used to quantify fluid flow

\[
\text{Re} = \frac{\nu D \rho}{\eta} \\
\nu = \text{velocity of the liquid} \\
D = \text{diameter of the channel} \\
\rho, \ \eta = \text{density and viscosity of the liquid}
\]

If \( \text{Re} < 2000 \) laminar flow, \( 2000 < \text{Re} < 20000 \) mixture of laminar and turbulent flow, \( \text{Re} > 20000 \) turbulent flow

Fluidity consists of 2 basic factors:

- Characteristics of the molten metal
- Casting parameters
Fluidity of Molten Metal

Viscosity
• Viscosity and viscosity index increase, fluidity decreases

Surface Tension
• High surface tension of the liquid metal reduces fluidity

Inclusions
• Inclusions can have a adverse effect on fluidity

Solidification Pattern of the Alloy
• Fluidity is inversely proportional to the freezing range

Mold Design
• Design and dimensions of the sprue, runners and risers influence fluidity
Fluidity of Molten Metal

Mold Material and its Surface Characteristics
• High thermal conductivity of the mold and the rough surfaces lower the fluidity

Degree of Superheat
• Superheat improves fluidity by delaying solidification

Rate of Pouring
• Slow rate of pouring lower the fluidity

One common test is to made molten metal flow along a channel at room temperature

The distance the metal flows before it solidifies and stops flowing is a measure of its fluidity
Two Categories of Casting Processes

**Expendable mold processes** use an expendable mold which must be destroyed to remove casting
- Mold materials: sand, plaster, and similar materials, plus binders

**Permanent mold processes** use a permanent mold which can be used to produce many castings
- Made of steel, bronze, refractory metal alloys, graphite
- Typically used for low Tm metals and alloys
  - Aluminum, copper, magnesium alloys
  - Automobile pistons, cylinder heads, connecting rods, etc.
Molding Processes

Expendable mold
• Permanent pattern: Sand casting (most prevalent), Shell-mold casting, Plaster-mold casting, Ceramic-mold casting, Vacuum casting
• Expendable pattern: Evaporative pattern casting (lost foam), Investment casting (lost-wax process)

Permanent mold
• Gravity casting, Slush casting, Pressure casting, Die casting, Centrifugal casting, Squeeze casting
• **Pros:** Good surface finish, Uniform/good mechanical properties, Close dimensional tolerance
• **Cons:** Not good for intricate shapes, Long lead time, not suitable for small production
Outline of production steps in a typical sand-casting operation.
Design for Ease of Removal from Mold

Poor

Good

Damage  Pattern  Draft angle

Flask  Sand mold
Sand Cores

(a) Cavity, Core, Parting line, Core prints, Mold

(b) Cavity, Chaplet, Core, Core prints
Vertical Flaskless Molding

(a) Ram force

(b) Metal poured here
Sand Casting Operation

(a) Mechanical drawing of part
(b) Cope pattern plate
(c) Drag pattern plate
(d) Core boxes
(e) Core halves pasted together
(f) Cope ready for sand
(g) Cope after ramming with sand and removing pattern, sprue, and risers
(h) Drag ready for sand
(i) Drag after removing pattern
(j) Drag with core set in place
(k) Cope and drag assembled and ready for pouring
(l) Casting as removed from mold; heat treated
(m) Casting ready for shipment
Shell-Molding Process

1. Pattern rotated and clamped to dump box
2. Pattern and dump box rotated
3. Pattern and dump box in position for the investment
4. Pattern and shell removed from dump box
5. Mold halves joined together
6. Mold placed in flask and metal poured
Evaporative Pattern Casting

1. Pattern molding
2. Cluster assembly
3. Coating
4. Compacted in sand
5. Casting
6. Shakeout
Evoparative Pattern Casting

Metal is poured into a mold for lost-foam casting of a 60-hp, three-cylinder marine engine

Finished engine block
Ceramic Mold Casting

1. Pouring slurry

2. Stripping green mold

3. Burn-off
Investment (lost-wax) Casting
A robot generates a ceramic shell on wax patterns (trees) for investment casting. The robot is programmed to dip the trees and then place them in an automated drying system. With many layers, a thick ceramic shell suitable for investment casting is formed.
Investment casting of an integrally cast rotor for a gas turbine. (a) Wax pattern assembly. (b) Ceramic shell around wax pattern. (c) Wax is melted out and the mold is filled, under a vacuum, with molten superalloy. (d) The cast rotor, produced to net or near-net shape.
Rotor Microstructure

Microstructure of a rotor that has been investment cast (top) and conventionally cast (bottom).
Vacuum-Casting Process

Diagram showing the vacuum-casting process with labeled parts:
- Mold
- Gate
- Vacuum
- Casting
- Molten metal
- Induction furnace
The pressure casting process, utilizing graphite molds for the production of steel railroad
Hot-Chamber Die Casting

Schematic illustration of the hot-chamber die-casting process.
Cold-Chamber Die Casting

Schematic illustration of the cold-chamber die-casting process. These machines are large compared to the size of the casting, because high forces are required to keep the two halves of the die closed under pressure.
# Properties of Die-Casting Alloys

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Ultimate Tensile Strength (MPa)</th>
<th>Yield Strength (MPa)</th>
<th>Elongation in 50 mm (%)</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum 380 (3.5 Cu-8.5 Si)</td>
<td>320</td>
<td>160</td>
<td>2.5</td>
<td>Appliances, automotive components, electrical motor frames and housings, engine blocks.</td>
</tr>
<tr>
<td>Aluminum 13 (12 Si)</td>
<td>300</td>
<td>150</td>
<td>2.5</td>
<td>Complex shapes with thin walls, parts requiring strength at elevated temperatures</td>
</tr>
<tr>
<td>Brass 858 (60 Cu)</td>
<td>380</td>
<td>200</td>
<td>15</td>
<td>Plumbing fixtures, lock hardware, bushings, ornamental castings</td>
</tr>
<tr>
<td>Magnesium AZ91B (9 Al - 0.7 Zn)</td>
<td>230</td>
<td>160</td>
<td>3</td>
<td>Power tools, automotive parts, sporting goods</td>
</tr>
<tr>
<td>Zinc No. 3 (4 Al)</td>
<td>280</td>
<td>—</td>
<td>10</td>
<td>Automotive parts, office equipment, household utensils, building hardware, toys</td>
</tr>
<tr>
<td>Zinc No. 5 (4 Al - 1 Cu)</td>
<td>320</td>
<td>—</td>
<td>7</td>
<td>Appliances, automotive parts, building hardware, business equipment</td>
</tr>
</tbody>
</table>

*Source: The North American Die Casting Association*

**TABLE 5.6** Properties and typical applications of common die-casting alloys.
Types of Cavities in Die-Casting Die

- Single-cavity die
- Multiple-cavity die
- Combination die
- Unit die
Centrifugal Casting

Schematic illustration of the centrifugal casting process.

Pipes, cylinder liners, and similarly shaped hollow parts can be cast by this process.
(a) Schematic illustration of the semicentrifugal casting process. Wheels with spokes can be cast by this process.

(b) Schematic illustration of casting by centrifuging. The molds are placed at the periphery of the machine, and the molten metal is forced into the molds by centrifugal forces.
Squeeze-Casting

Sequence of operations in the squeeze-casting process. This process combines the advantages of casting and forging.
Turbine Blade Casting

Methods of casting turbine blades:
(a) directional solidification;
(b) method to produce a single-crystal blade;
(c) a single-crystal blade with the constriction portion still attached.
Melt-Spinning Process

(a) Schematic illustration of the melt-spinning process to produce thin strips of amorphous metal. (b) Photograph of nickel-alloy production through melt-spinning.
## Selecting Casting Processes

<table>
<thead>
<tr>
<th>Process</th>
<th>Advantages</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>Almost any metal is cast; no limit to size, shape or weight; low tooling cost.</td>
<td>Some finishing required; somewhat coarse finish; wide tolerances.</td>
</tr>
<tr>
<td>Shell mold</td>
<td>Good dimensional accuracy and surface finish; high production rate.</td>
<td>Part size limited; expensive patterns and equipment required.</td>
</tr>
<tr>
<td>Expendable pattern</td>
<td>Most metals cast with no limit to size; complex shapes</td>
<td>Patterns have low strength and can be costly for low quantities.</td>
</tr>
<tr>
<td>Plaster mold</td>
<td>Intricate shapes; good dimensional accuracy and finish; low porosity.</td>
<td>Limited to nonferrous metals; limited size and volume of production; mold making time relatively long.</td>
</tr>
<tr>
<td>Ceramic mold</td>
<td>Intricate shapes; close tolerance parts; good surface finish.</td>
<td>Limited size.</td>
</tr>
<tr>
<td>Investment</td>
<td>Intricate shapes; excellent surface finish and accuracy; almost any metal cast.</td>
<td>Part size limited; expensive patterns, molds, and labor.</td>
</tr>
<tr>
<td>Permanent mold</td>
<td>Good surface finish and dimensional accuracy; low porosity; high production rate.</td>
<td>High mold cost; limited shape and intricacy; not suitable for high-melting-point metals.</td>
</tr>
<tr>
<td>Die</td>
<td>Excellent dimensional accuracy and surface finish; high production rate.</td>
<td>Die cost is high; part size limited; usually limited to nonferrous metals; long lead time.</td>
</tr>
<tr>
<td>Centrifugal</td>
<td>Large cylindrical parts with good quality; high production rate.</td>
<td>Equipment is expensive; part shape limited.</td>
</tr>
</tbody>
</table>
Defects in casting

**Metallic projections:** fins, flash, rough surfaces or swells

**Cavities:** round or rough internal and external cavities. Blowholes, pinholes, and shrinkage cavities

**Discontinuities:** cracks, cold or hot tearing and cold shots.

**Defective surfaces:** surface folds, laps, scars, adhering sand layers and oxide scale.

**Incomplete castings:** misruns, runouts.

**Incorrect dimensions or slope**

Inclusions
Sand Casting Defects

**Sand Blow:** Balloon-shaped gas cavity caused by release of mold gases during pouring

**Pin Holes:** Formation of many small gas cavities at or slightly below surface of casting

**Penetration:** When fluidity of liquid metal is high, it may penetrate into sand mold or core, causing casting surface to consist of a mixture of sand grains and metal

**Mold Shift:** A step in the cast product at parting line caused by sidewise relative displacement of cope and drag
**General Defects**

**Shrinkage Cavity:** Depression in surface or internal void caused by solidification shrinkage that restricts amount of molten metal available in last region to freeze.

**Cold Shut:** Two portions of metal flow together but there is a lack of fusion due to premature freezing.

**Cold Shot:** Metal splatters during pouring and solid globules form and become entrapped in casting.

**Misrun:** A casting that has solidified before completely filling mold cavity.
Heat Treatment Processes

Why heat treatment?

Heat treatments are processes of controlled heating and cooling to purposefully alter a material’s structure and properties (strength, toughness, ductility, etc)

Changes in properties can be introduced with no change in shape

Heat treatments are integrated with other processes to obtain effective results
Steel is the most common material to be heat treated.

Isothermal transformation (I-T) or time-temperature-transformation (T-T-T) diagrams are used to understand the process.

Phase transformations are most rapid at an intermediate temperature.

Upon being rapidly cooled, a portion of austenite (dependent on alloy composition) will transform to martensite, a hard, brittle crystalline structure.

**Strengthening Heat Treatments for Steel**
Martensite: when austenite is cooled rapidly, the fcc structure is transformed to a body centered tetragonal structure

- Fewer slip systems than fcc
- Carbon is in interstitial position
- Hard and brittle, lacks toughness

Tempering is a process of heat treatment, which is used to reduce brittleness, increase the toughness and ductility, reduce residual stress in ferrous alloys

The metal is heated to a specific temperature (depending on composition) and cooled at a prescribed rate

Tempered martensite (alfa+ very fine FeC particles)
Annealing

(i) Heating to a specific temperature in furnace, (ii) holding at that temperature for a period of time, (iii) cooling the workpiece, in air or a furnace

- Full annealing: cooling slowly in a furnace – coarse pearlite
- Normalizing: cooling in still air – fine pearlite
- Speroidizing: just below eutectoid T and held for a period of time - spheroidities
Additional Annealing Processes

**Process annealing**

– Recrystallization is induced after a material has been cold worked to reduce strain hardening effects

– Induces a change in size, shape, and distribution

**Stress-relief annealing**

– Reduces residual stresses in casting, welded assemblies, and cold-formed products

– Materials are heated and then slowly cooled
Case Hardening

Methods to only change the surface properties

– Selective heating of the surface
– Altered surface chemistry
– Deposition of an additional surface layer

Surface treatments for steel

– Flame hardening
– Induction hardening
– Laser beam hardening
– Electron beam hardening
General Design Considerations

1. Design the part so that the shape is easily cast

2. Select a casting process and material suitable for the part, size, dimensional accuracy, surface texture and mechanical properties

3. Locate the parting line of mold/die

4. Locate and design gating system to allow uniform feeding of the mold cavity with molten metal. Include risers, sprue and screens.

5. Ensure that proper controls and good practices in place.
Product Design Considerations

Geometric simplicity

• Although casting can be used to produce complex part geometries, simplifying the part design usually improves castability

• Avoiding unnecessary complexities:
  ➢ Simplifies mold-making
  ➢ Reduces the need for cores
  ➢ Improves the strength of the casting

Corners on the casting

• Sharp corners and angles should be avoided, since they are sources of stress concentrations and may cause hot tearing and cracks

• Generous fillets should be designed on inside corners and sharp edges should be blended

Uniform Cross sections and smooth blending between sections
Elimination of Porosity in Castings

(a) Suggested design modifications to avoid defects in castings. Note that sharp corners are avoided to reduce stress concentrations; (b, c, d) examples of designs showing the importance of maintaining uniform cross-sections in castings to avoid hot spots and shrinkage cavities.
Avoid Unnecessary Complexities

Design change to eliminate need for using a core: (a) original design, and (b) redesign

Large flat areas should be avoided because of warping or uneven surface finish. Add ribs and serrations.
Elimination of Porosity

Various types of (a) internal and (b) external chills (dark areas at corners), used in castings to eliminate porosity caused by shrinkage. Chills are placed in regions where there is a larger volume of metal, as shown in (c).
Product Design Considerations

Dimensional Tolerances and Surface Finish

• Dimensional accuracy and finish vary significantly, depending on process
  ➢ Poor dimensional accuracies and finish for sand casting
  ➢ Good dimensional accuracies and finish for die casting and investment casting
  ➢ Tolerance: \( \sim \pm 0.8 \) mm for small \( \sim \pm 6 \) mm for large parts

• Pattern’s makers shrinkage allowance: 10-20mm/m

Machining Allowances

• Almost all sand castings must be machined to achieve the required dimensions and part features
• Additional material, called the machining allowance, is left on the casting in those surfaces where machining is necessary
• Typical machining allowances for sand castings are around 1.5 and 3 mm (1/16 and 1/4 in)
Product Design Considerations

Draft Guidelines

• In expendable mold casting, draft facilitates removal of pattern from mold
  ➢ Draft = 1° for sand casting
• In permanent mold casting, purpose is to aid in removal of the part from the mold
  ➢ Draft = 2° to 3° for permanent mold processes
• Similar tapers should be allowed for solid cores

Finishing

• Consider subsequent finishing
• Machining allowance
• Machining considerations
Design Principles for permanent mold casting

- Use radii or fillets to avoid corners and provide uniform cross-section.
- Deep cavities should be on one side of the casting where possible.
- Wall sections should be uniform.
- Ribs and/or fillets improve bosses.
- Sloping bosses can be designed for straight die parting to simplify die design.
- Side cores can be eliminated with this hole design.
Sprue Design

Single runner for simple parts. Two-runner for complex parts.

Use runners to trap dross

Calculate/design risers so the metal in risers solidifies after casting

Riser volume should be large enough to compensate for shrinkage

Junctions between the casting feeder should be designed to avoid hot spots and porosity.

Riser should be position to where most material needed

There must be sufficient pressure (not suitable for low-density alloys)

Design/calculate sprue to avoid turbulence and aspirations
Parting Line Location

Influences mold design, ease of molding, number of cores, gating system etc.

Minimize casting height and larger portion low

Orient to avoid porosity

Along flat plane not around contoured surfaces

At the corners and edges

Placed as low as possible for less-dense materials (aluminum) and around the midheight for denser materials (steel).
Gate Design and Location

Multiple gates for large parts

Direct gates for thick sections

Place a fillet between a gate and a casting.

Place the gate with sprue sufficiently far away so it can be easily removed.

Minimum gate length: 3-5 x gate diameter

Avoid curved gates