CASTING PROCESS - 5

Assoc Prof Zainal Abidin Ahmad
Department of Manufacturing & Ind. Eng.
Universiti Teknologi Malaysia

METAL CASTING PROCESSES

- Casting Quality
- Metals for Casting
- Product Design Considerations

Casting Quality

- There are numerous opportunities for things to go wrong in a casting operation, resulting in quality defects in the product
- The defects can be classified as follows:
  - Defects common to all casting processes
  - Defects related to sand casting process

Misrun

A casting that has solidified before completely filling mold cavity

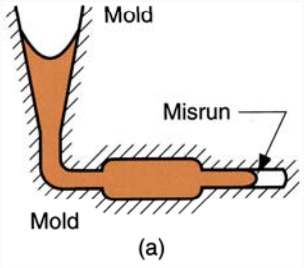


Figure 11.22 - Some common defects in castings: (a) misrun

Cold Shut

Two portions of metal flow together but there is a lack of fusion due to premature freezing

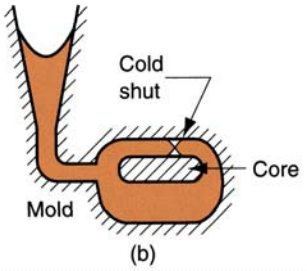


Figure 11.22 - Some common defects in castings: (b) cold shut

Cold Shot

Metal splatters during pouring and solid globules form and become entrapped in casting

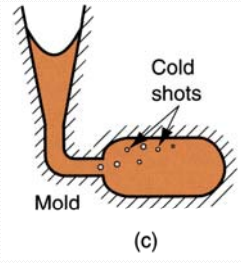


Figure 11.22 - Some common defects in castings: (c) cold shot

Shrinkage Cavity

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

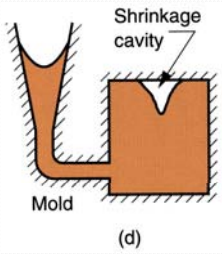


Figure 11.22 - Some common defects in castings: (d) shrinkage cavity

Sand Blow

Balloon-shaped gas cavity caused by release of mold gases during pouring

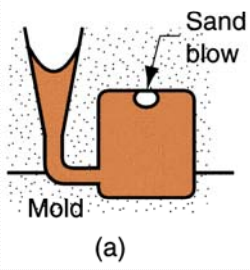


Figure 11.23 - Common defects in sand castings: (a) sand blow

Pin Holes

Formation of many small gas cavities at or slightly below surface of casting

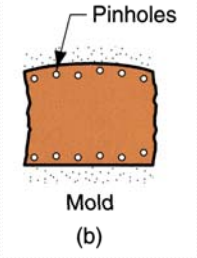


Figure 11.23 - Common defects in sand castings: (b) pin holes

Penetration

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

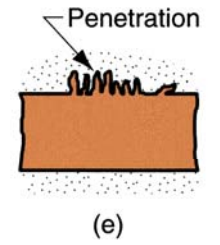


Figure 11.23 - Common defects in sand castings: (e) penetration

Mold Shift

A step in cast product at parting line caused by sidewise relative displacement of cope and drag

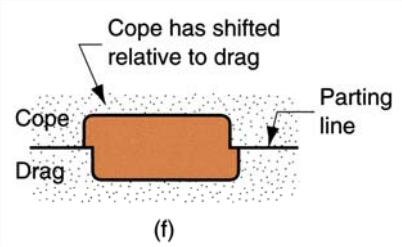


Figure 11.23 - Common defects in sand castings: (f) mold shift

Metals for Casting

- Most commercial castings are made of alloys rather than pure metals
  - Alloys are generally easier to cast, and properties of product are better
- Casting alloys can be classified as:
  - Ferrous
  - Nonferrous

Ferrous Casting Alloys: Cast Iron

- Most important of all casting alloys
- Tonnage of cast iron castings is several times that of all other metals combined
- Several types: (1) gray cast iron, (2) nodular iron, (3) white cast iron, (4) malleable iron, and (5) alloy cast irons
- Typical pouring temperatures ~ 1400°C (2500°F), depending on composition

Ferrous Casting Alloys: Steel

- The mechanical properties of steel make it an attractive engineering material
- The capability to create complex geometries makes casting an attractive shaping process
- Difficulties faced by the foundry working with steel:
  - Pouring temperature of steel is higher than for most other casting metals ~ 1650°C (3000°F)
  - At these temperatures, steel readily oxidizes, so molten metal must be isolated from air
  - Molten steel has relatively poor fluidity

Nonferrous Casting Alloys: Aluminum

- Generally considered to be very castable
- Pouring temperatures low – melting temperature of aluminum T_m = 660°C (1220°F)
- Properties:
  - Light weight
  - Range of strength properties by heat treatment
  - Ease of machining

Nonferrous Casting Alloys: Copper Alloys

- Includes bronze, brass, and aluminum bronze
- Properties:
  - Corrosion resistance
  - Attractive appearance
  - Good bearing qualities
- Limitation: high cost of copper
- Applications: pipe fittings, marine propeller blades, pump components, ornamental jewelry

Nonferrous Casting Alloys: Zinc Alloys

- Highly castable, commonly used in die casting
- Low melting point – melting point of zinc T_m = 419°C (786°F)
- Good fluidity for ease of casting
- Properties:
  - Low creep strength, so castings cannot be subjected to prolonged high stresses

Typical Applications for Casting and Casting Characteristics

TABLE 12.2

Type of alloy	Application	Castability*	Weldability*	Machinability*
Aluminum	Pistons, clutch housings, intake manifolds	E	F	G–E
Copper	Pumps, valves, gear blanks, marine propellers	F–G	F	F–G
Ductile iron	Crankshafts, heavy-duty gears	G	D	G
Gray iron	Engine blocks, gears, brake disks and drums, machine bases	E	D	G
Magnesium	Crankcase, transmission housings	G–E	G	E
Malleable iron	Farm and construction machinery, heavy-duty bearings, railroad rolling stock	G	D	G
Nickel	Gas turbine blades, pump and valve components for chemical plants	F	F	F
Steel (carbon and low alloy)	Die blocks, heavy-duty gear blanks, aircraft undercarriage members, rail-road wheels	F	E	F
Steel (high alloy)	Gas turbine housings, pump and valve components, rock crusher jaws	F	E	F
White iron	Mill liners, shot blasting nozzles, railroad brake shoes, crushers and pulverizers	G	VP	VP
Zinc	Door handles, radiator grills,	E	D	E

*E, excellent; G, good; F, fair; VP, very poor; D, difficult.

Product Design Considerations: Geometric Simplicity

- Although casting can be used to produce complex part geometries, simplifying the part design will improve castability
- Avoiding unnecessary complexities:
  - Simplifies mold-making
  - Reduces the need for cores
  - Improves the strength of the casting

- Minor changes in part design can reduce need for coring

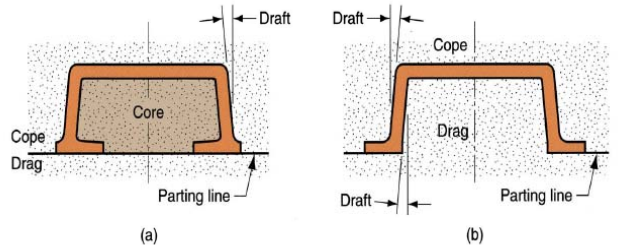


Figure 11.25 – Design change to eliminate the need for using a core: (a) original design, and (b) redesign

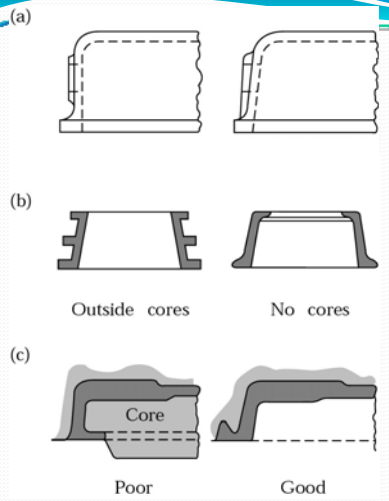


Figure 12.6 Examples of casting design modifications. *Source*: *Steel Casting Handbook*, 5th ed. Steel Founders' Society of America, 1980.

Product Design Considerations:

Corners

- 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

Casting Design Modifications

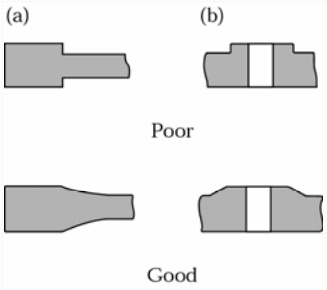


Figure 12.1 Suggested design modifications to avoid defects in castings. Note that sharp corners are avoided to reduce stress concentrations.

Casting Cross-Sections

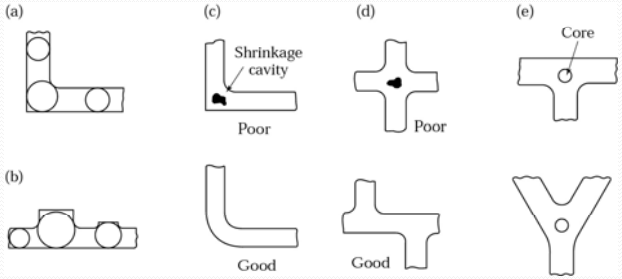
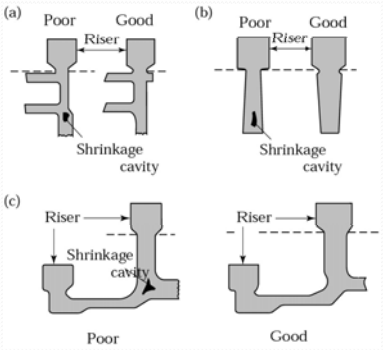


Figure 12.2 Examples of designs showing the importance of maintaining uniform cross- sections in castings to avoid hot spots and shrinkage cavities.

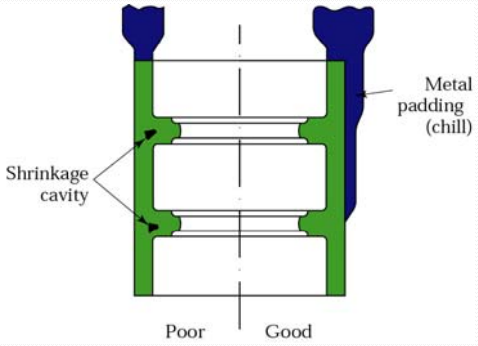
Avoiding Shrinkage Cavities

Figure 12.3 Examples of design modifications to avoid shrinkage cavities in castings. *Source*: *Steel Castings Handbook*, 5th ed. Steel Founders' Society of America, 1980. Used with permission.



Chills

Figure 12.4 The use of metal padding (chills) to increase the rate of cooling in thick regions in a casting to avoid shrinkage cavities.



Product Design Considerations: Draft Guidelines

- In expendable mold casting, purpose of draft is to facilitate removal of pattern from mold (1° for sand casting)
- In permanent mold casting, purpose is to aid in removal of the part from the mold (2° to 3° for permanent mold processes)
- Similar tapers should be allowed if solid cores are used

Product Design Considerations: Dimensional Tolerances and Surface Finish

Significant differences in dimensional accuracies and finishes can be achieved in castings, depending on process:

- Poor dimensional accuracies and finish for sand casting
- Good dimensional accuracies and finish for die casting and investment casting

Product Design Considerations: Machining Allowances

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

Normal Shrinkage Allowance for Some Metals Cast in Sand Molds

TABLE 12.1

Metal	Percent
Gray cast iron	0.83–1.3
White cast iron	2.1
Malleable cast iron	0.78–1.0
Aluminum alloys	1.3
Magnesium alloys	1.3
Yellow brass	1.3–1.6
Phosphor bronze	1.0–1.6
Aluminum bronze	2.1
High-manganese steel	2.6

Parting Lines

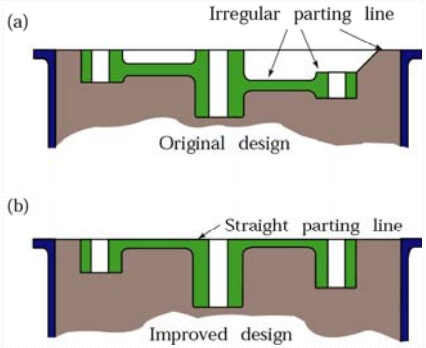


Figure 12.5 Redesign of a casting by making the parting line straight to avoid defects. *Source*: *Steel Casting Handbook*, 5th ed. Steel Founders' Society of America, 1980.

Desirable and Undesirable Die-Casting Practices

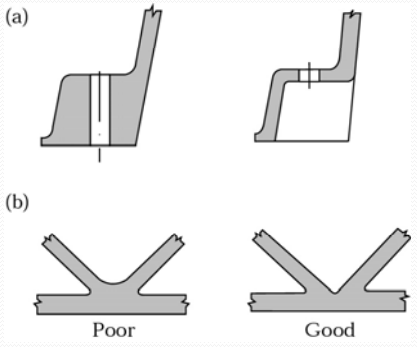


Figure 12.7 Examples of undesirable and desirable design practices for die-cast parts. Note that section-thickness uniformity is maintained throughout the part. *Source*: American Die Casting Institute.