BMM3643 Manufacturing Processes
Metal Casting Processes
(Sand Casting)

by
Dr Mas Ayu Bt Hassan
Faculty of Mechanical Engineering
masszee@ump.edu.my

Chapter Synopsis

This chapter will expose students to various types of metal casting processes used for converting raw materials into required products by solidify the metal. Types of metals used and proper selection of casting process will influence design considerations, product quality, and production costs.

Chapter Information

Lesson Objectives:

Sand Casting

Lesson Objective:

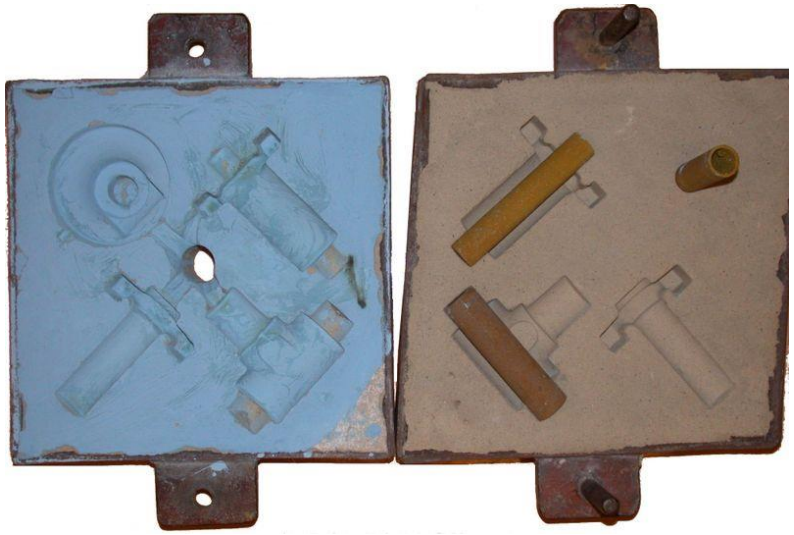
At the end of this lecture, students should be able to understand and explain the following:

- Fundamentals of Sand Casting process
- Sand Casting Features and Functions
- Advantages and limitations of Sand Casting
- Casting defects & design consideration

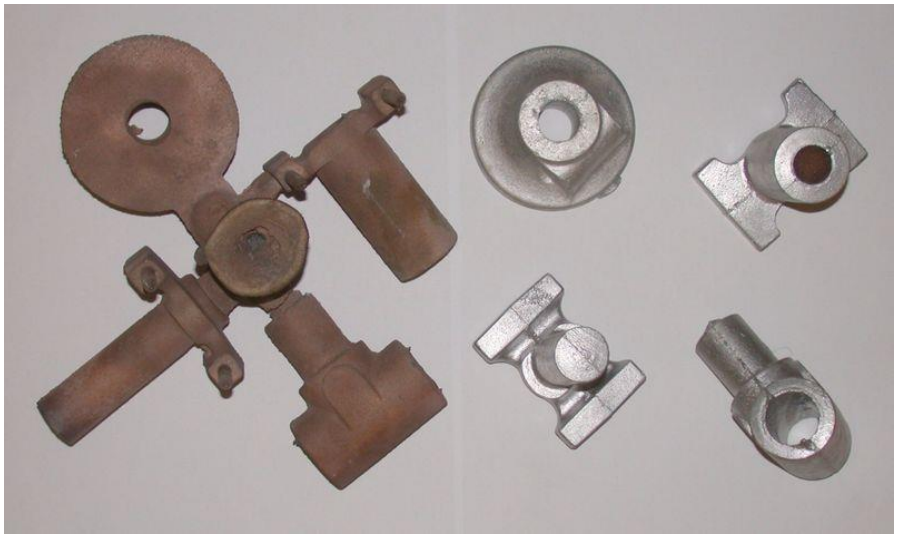
Sand Casting

- **Definition of casting:** pouring liquid metal into a cavity of the shape to be made and allowing it to solidify.
- The mold cavity is made using a pattern which the mold is formed.
- The pattern is then removed before pouring the liquid metal into the mold.
- The mold material extracts heat from the liquid and the metal solidifies according to the shape of the mold cavity.
- The solidified metal shape is then removed from the mold as well as other excess metal such as gates, runners and risers.
- The solidified metal component is also called the casting.

Sand Casting Equipment & Product

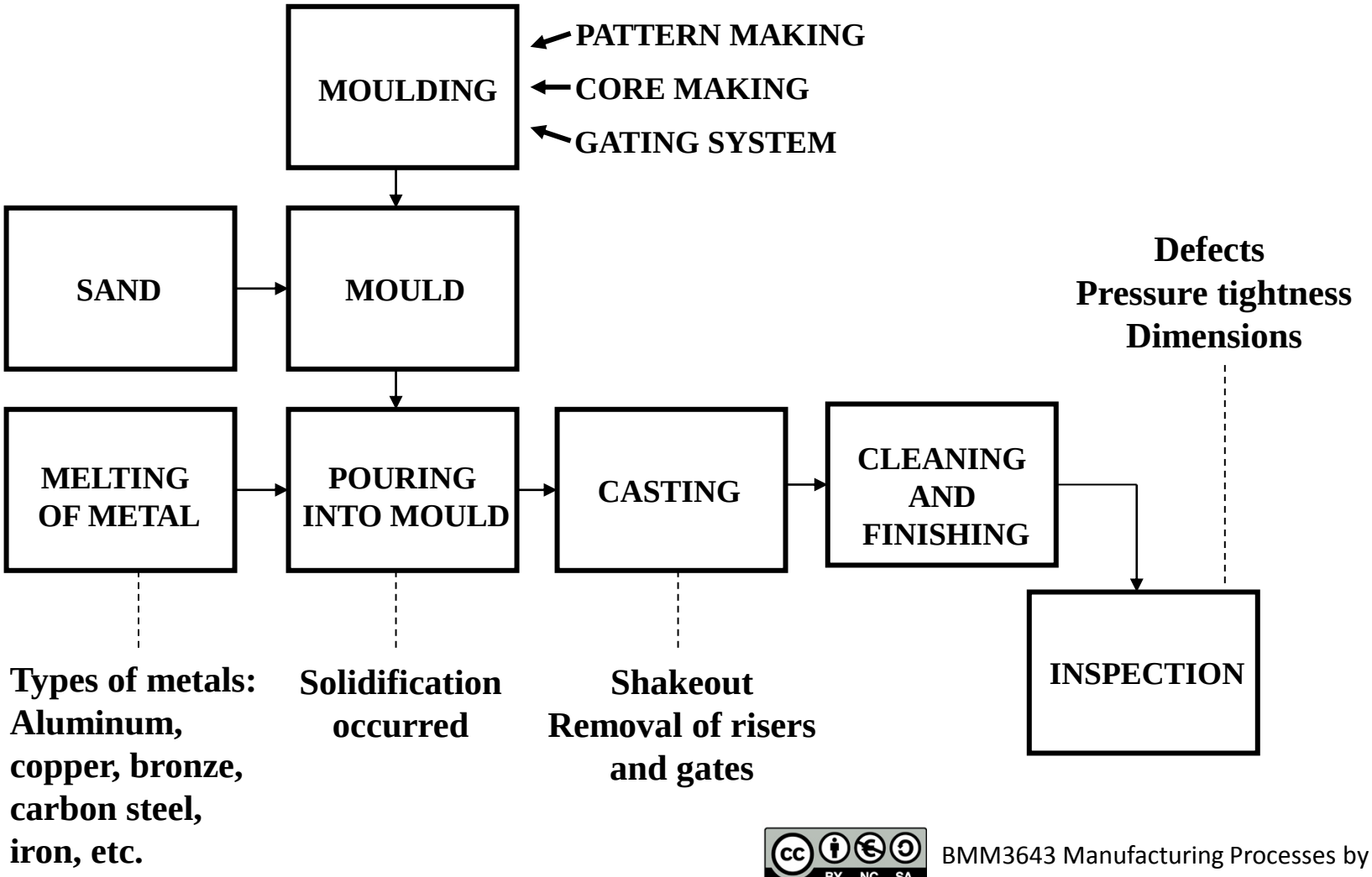


Cope & drag (top and bottom halves of a sand mold), with cores in place on the drag. Source by commons.wikimedia.org



Two sets of castings product made from bronze and aluminum produced from sand mold. Source by commons.wikimedia.org

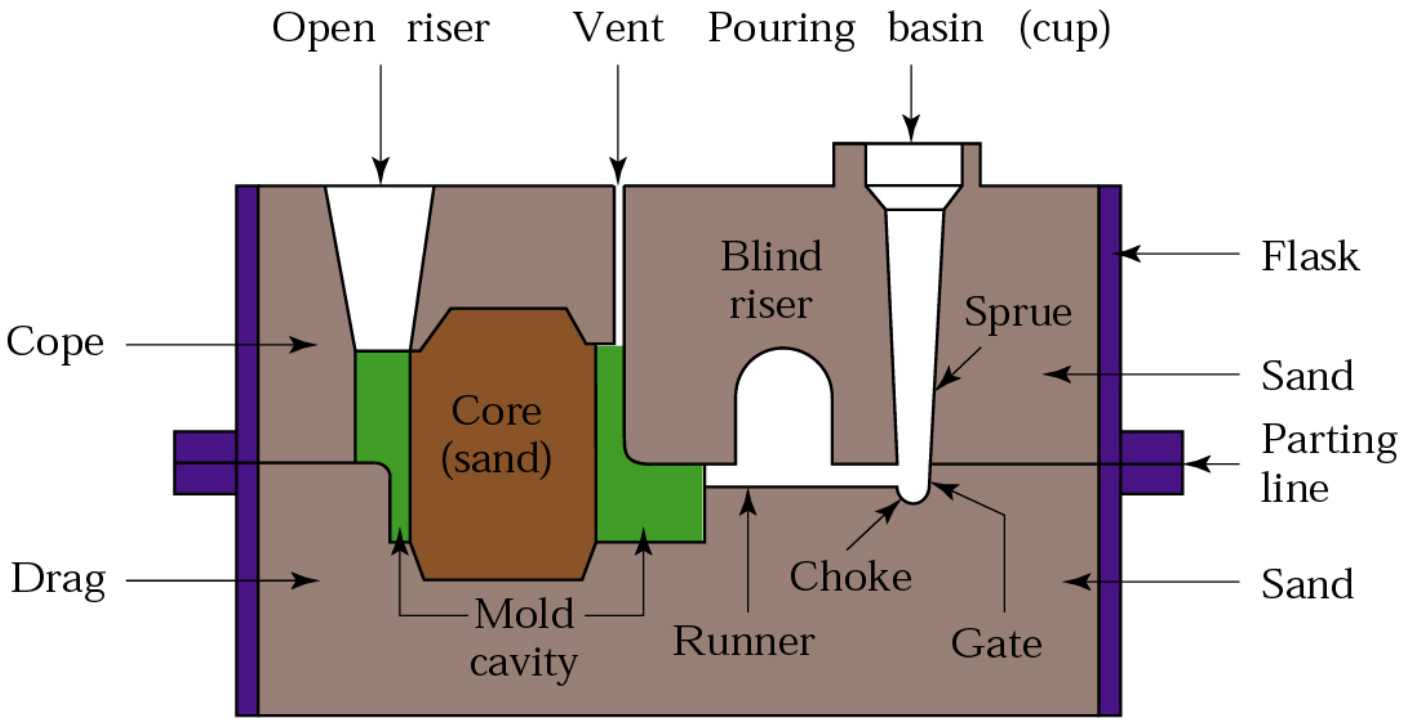
Sand Casting Process



What is molding sand?

- Three criteria of molding sand are:
  1. Availability - it is inexpensive
  2. Reusability - it is easily recycled
  3. Thermal stability - it can withstand extremely high temperatures without cracking
  4. Permeability - ability of a sand mold to permit the escape of gases and steam during the casting process
- Molding sand are made from mixture of **green sand** (an aggregate of sand, pulverized coal, bentonite clay, and water) which is **traditionally** been used in sand casting.
- Nowadays, modern **chemically bonded molding systems** are becoming more popular. The most widely used casting sand is **silica (SiO_2).**

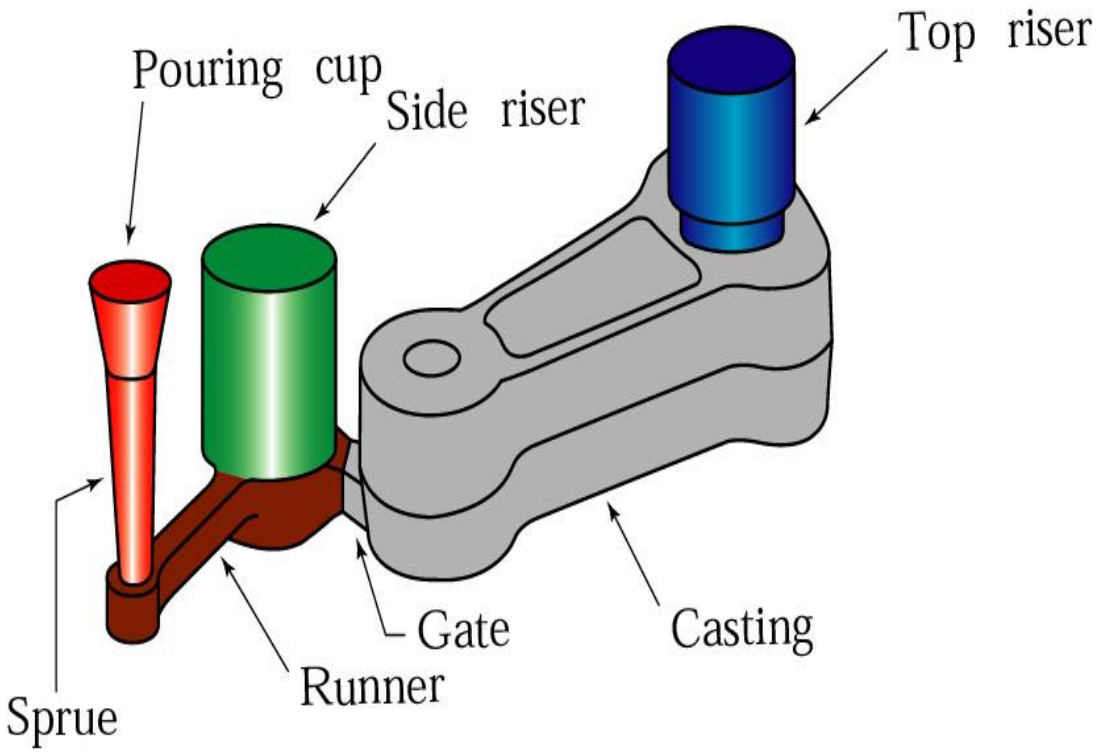
Sand Mold Features



Schematic illustration of a sand mold, showing various features. Source by Kalpakjian, 2014.

Riser & Gating System

Schematic of a simple riser gating system. Risers serve as **reservoirs**, to provide sufficient liquid metal to the casting to compensate shrinkage during solidification. *Source*: American Foundrymen's Society.



Casting Terminology

- A pattern is an approximate duplicate of the final casting.
- Molding material is used to pack around the pattern (made of green sand).
- A flask is type of tooling used to contain a mold in metal casting., consist of cope (top) and drag (bottom) (e.g. made of steel, aluminum or woods).
- A core is a shape that is inserted into a mold to produce the internal features of a casting (holes, passages).
- A mould cavity is the shaped hole into which the molten metal is poured and solidified to produce the desired casting product.
- A riser is an extra void created in the mold to provide a reservoir of molten metals flow into the mold cavity in order to compensate any shrinkage.

Casting Terminology (continue)

- The gating system is the network of connected channels used to deliver the molten metal to the mould cavity.
- The pouring cup is the portion of the gating system that firstly receives the molten metal.
- A sprue is the vertical portion of the gating system where molten metals travel down.
- A runner is a horizontal channel.
- A gate is used to control entrances of molten metals into mould cavity.
- A vent is used to provide an escape for the gaseous.

Casting Terminology (continue)

- The parting surface is the interface that divided the cope (top) and drag (bottom) halves of a mold.
- Draft is the taper on a pattern that allows ease of removal the castings from the mould.
- Casting is used to describe the process and the product after solidification.

Pattern Requirement in Sand Casting

- **Pattern** is a replica of the object to be cast that MUST have similar size, dimension and shape according to the desired product design.
- However, in making a pattern there are THREE pattern allowances should be considered, such as:
  1. **Shrinkage allowance (most important) -** Patterns are made larger than the casting to compensate **contraction** of the liquid while freezing.
  2. **Machining Allowance -** Allowance required to remove the rough cast surface, usually 2 to 25 mm (0.1 to 1")
  3. **Draft Allowance (slight taper) -** To facilitate ease of removal, usually ½ to 2°
  4. **Distortion Allowance –** Allowance provided on pattern due to the uneven shrinkage that cause castings to warp or distort during cooling period, also called as chamber.

SOLIDIFICATION CONTRACTION FOR VARIOUS CAST METALS (SHRINKAGE ALLOWANCE)

Metal or alloy	Volumetric solidification contraction (%)	Metal or alloy	Volumetric solidification contraction (%)
Aluminum	6.6	70%Cu–30%Zn	4.5
Al–4.5%Cu	6.3	90%Cu–10%Al	4
Al–12%Si	3.8	Gray iron	Expansion to 2.5
Carbon steel	2.5–3	Magnesium	4.2
1% carbon steel	4	White iron	4–5.5
Copper	4.9	Zinc	6.5

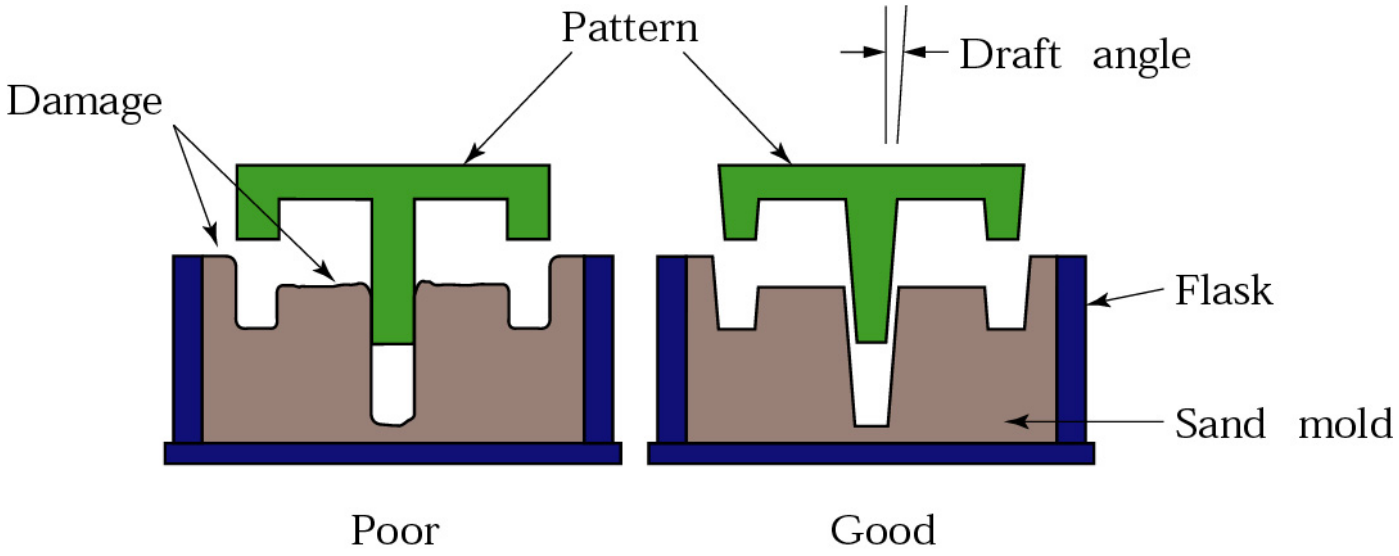
Source: After R. A. Flinn.

MACHINING ALLOWANCE

Type of metal and alloys	*Machining allowance (mm)*
Cast irons	
(i) Large size castings (>1000 mm)	10.0
(ii) Medium size castings (<150 mm)	3.0
Cast steels	
(i) Large size castings (>1000 mm)	12.0
(ii) Medium size castings (<150 mm)	4.3
Non-ferrous materials	
(i) Large size castings (>1000 mm)	5.0
(ii) Medium size castings (<150 mm)	1.5

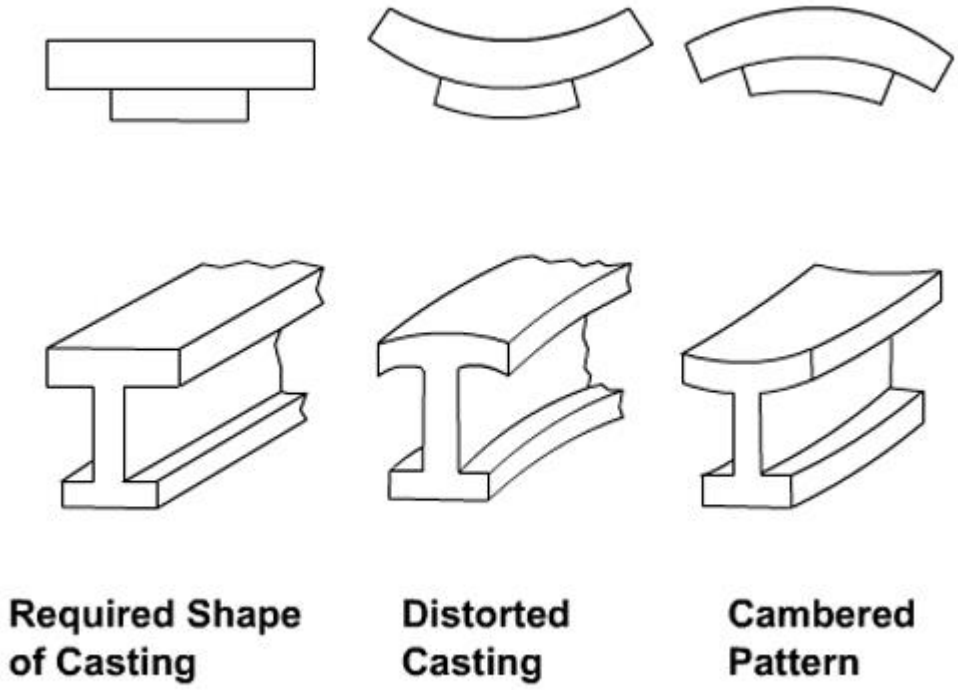
Standard of general machining allowance. *Source*: Kalpakjian, 2014.

DRAFT ALLOWANCE



Patterns with tapers for ease of removal from the sand mold. *Source*: Kalpakjian, 2014.

DISTORTION ALLOWANCE



Taper on patterns for ease of removal from the sand mold. *Source*: http://techminy.com.

Pattern Characteristics

- Lightweight –for handling and working
- Strong hard and durable
- Easy to work, shape and join
- Resistance to wear, abrasion, corrosion and chemical attack
- Easily available at low cost
- Easy to repair
- Ability to give good surface finish

Pattern Material Characteristic

			Rating[a]		
Characteristic	*Wood*	*Aluminum*	*Steel*	*Plastic*	*Cast iron*
Machinability	E	G	F	G	G
Wear resistance	P	G	E	F	E
Strength	F	G	E	G	G
Weight **b**	E	G	P	G	P
Repairability	E	P	G	F	G
Resistance to:					
Corrosion **c**	E	E	P	E	P
Swelling **c**	P	E	E	E	E

a E, Excellent; G, good; F, fair; P, poor.

b As a factor in operator fatigue.

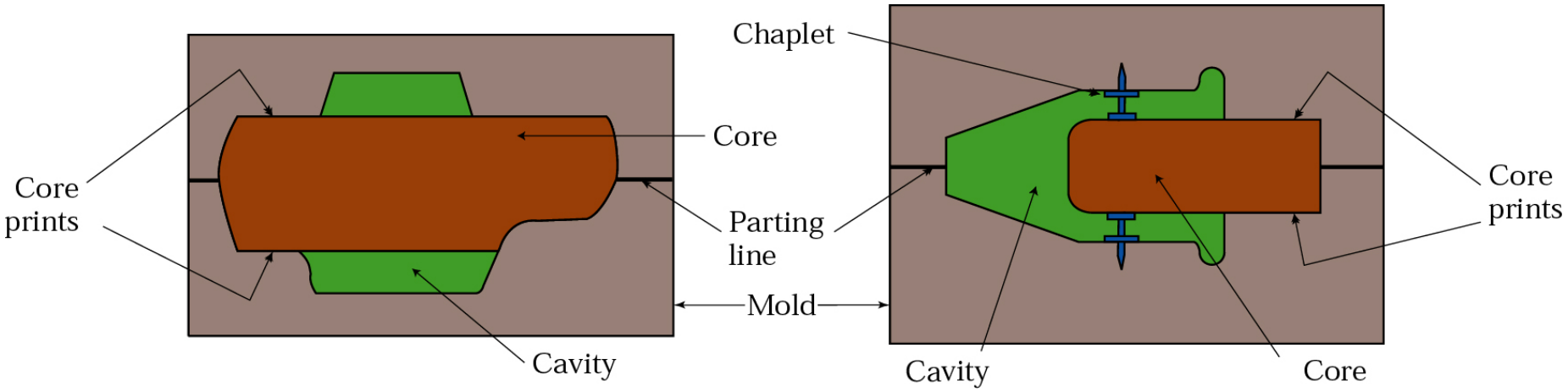
c By water.

Source: D.C. Ekey and W.R. Winter, Introduction to Foundry Technology. New York. McGraw-Hill, 1958.

Core and Cores Print in Sand Casting

- Cores are component that used to create cavities and hollow projections which normally cannot be produced by pattern alone.
- Any complicated contour or cavity can be made by means of cores so that really intricate shapes can be easily obtained.
- Generally made of sand mixture & binder (green sand, bentonite clay, pulverized coal, resin oil).
- Able to withstand more severe thermal and mechanical condition and must have higher strength than molding sand.

EXAMPLE OF CORES & CHAPLET



Schematics diagram showing core prints and chaplets to support cores. Source by Kalpakjian, 2014.

Requirements for core

- **There are 7 requirements for core:**
  1. **Green Strength**: In the green condition, there must be adequate strength for making & handling
  2. **Dry strength:** In the hardened state, it must be strong enough to handle the forces of casting; therefore, the compression strength should be 100 to 300 psi (0.69 to 2.07 MPa).
  3. **Permeability:** Must be very high to allow for the escape of gases.
  4. **Friability:** As the casting or molding cools, the core must be weak enough to break down as the material shrinks. Moreover, they must be easy to remove during shakeout.
  5. **Good refractoriness** is required as the core is usually surrounded by hot metal during casting or molding.
  6. **Smoothness:** For a smooth surface finish of casting.
  7. **Low gas emission:** Minimum generation of gases during metal pouring.

Advantages of sand casting

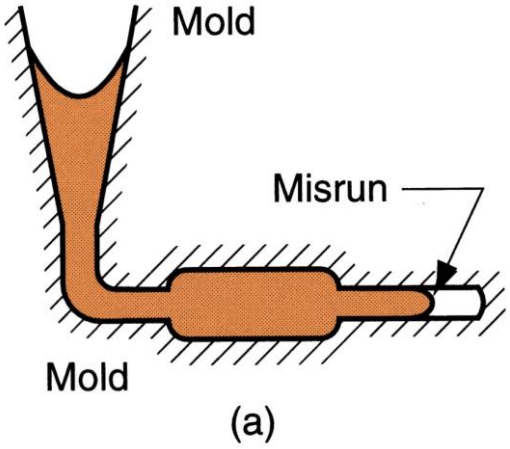
- **ADVANTAGES**
  - **Intricate shapes internal or external can be made**
  - **Almost all metals can be cast**
  - **Inexpensive and simple tools used**
  - **Ideal method for trial production or production of a small lot**
  - **Weight reduction in design can be achieved**
  - **Casting are generally cooled uniformly from all sides and therefore they are expected to have no directional properties**
  - **Any sizes of product can be cast**

Limitations of sand casting

- **LIMITATIONS**
  - **Dimensional accuracy and surface finished would not be adequate for final application in many cases**
  - **Labor intensive**
  - **Difficult to remove defects arising out of the moisture present in sand castings.**

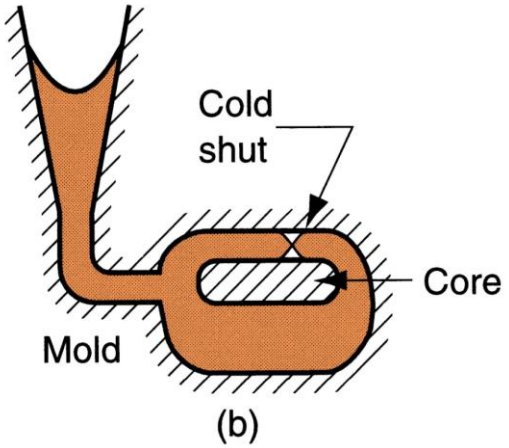
Casting Defects

- Some of common defects occurs in casting products:



Misrun

A casting that has solidified before completely filling mould cavity

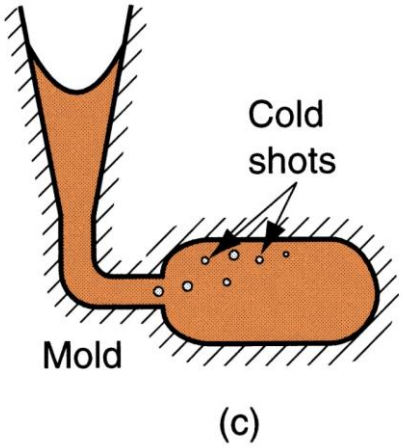


Cold Shut

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

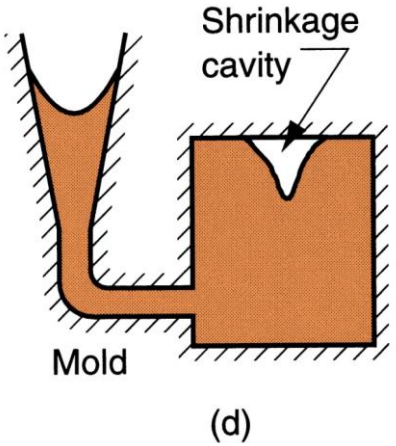
Source by Kalpakjian Book, 2014

Casting Defects (continue)



Cold Shot

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

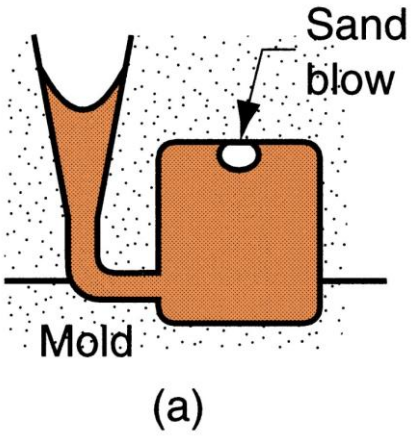


Shrinkage Cavity

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

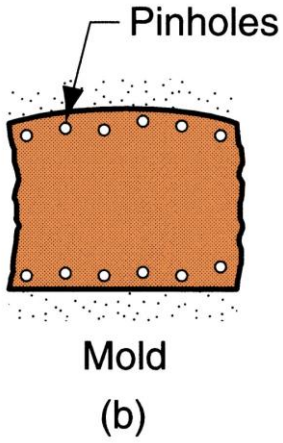
Source by Kalpakjian Book, 2014

Casting Defects (continue)



Sand Blow

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

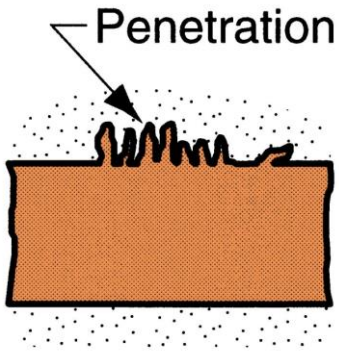


Pin Holes

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

Source by Kalpakjian Book, 2014

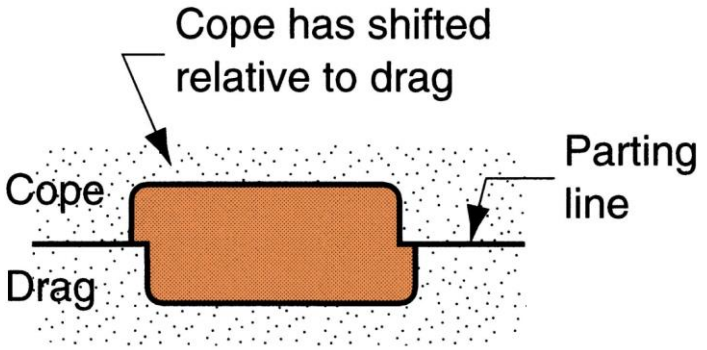
Casting Defects (continue)



(e)

Penetration

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



(f)

Mould Shift

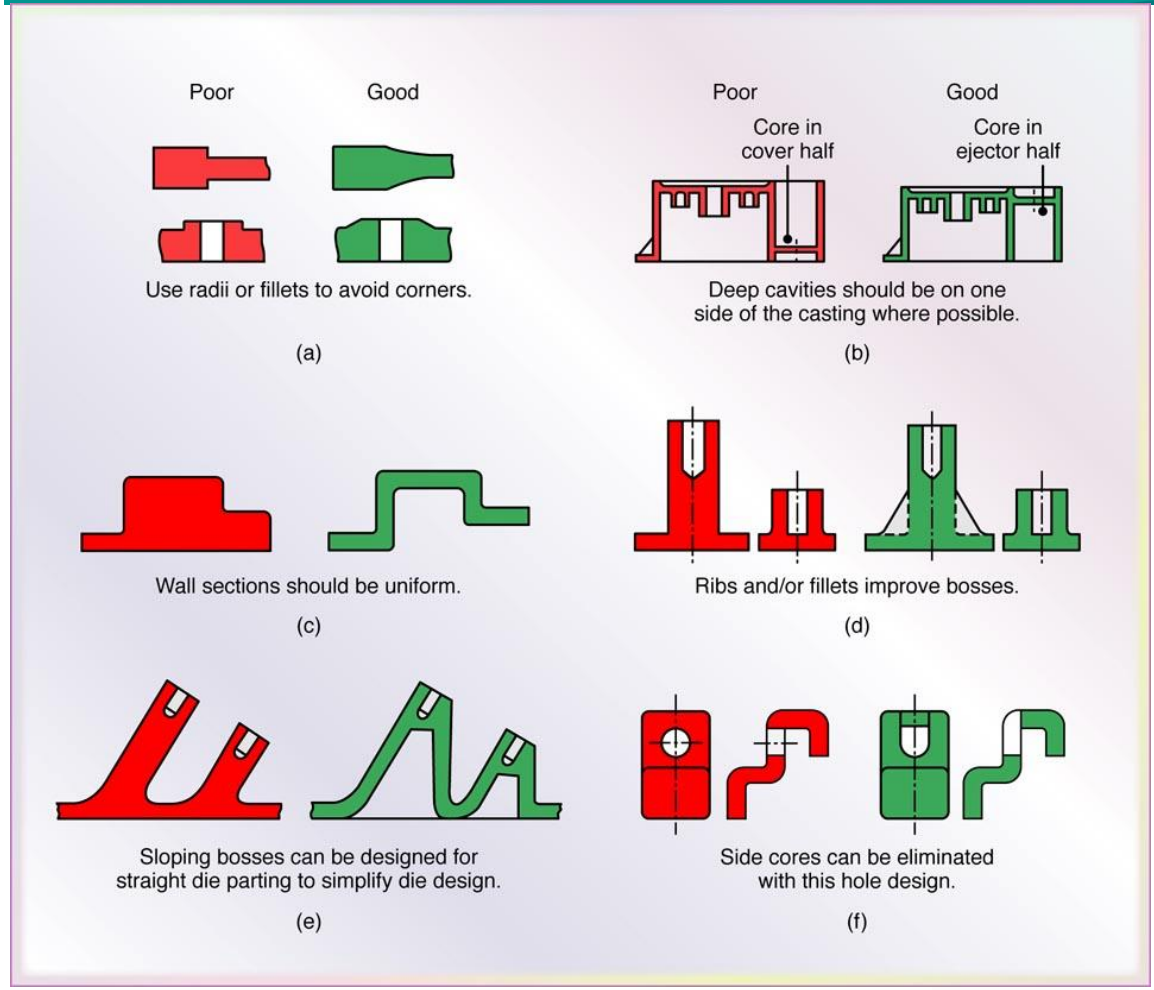
A step in cast product at parting line caused by sidewise relative displacement of cope and drag

Source by Kalpakjian Book, 2014

Design Rules & Considerations in Sand Casting

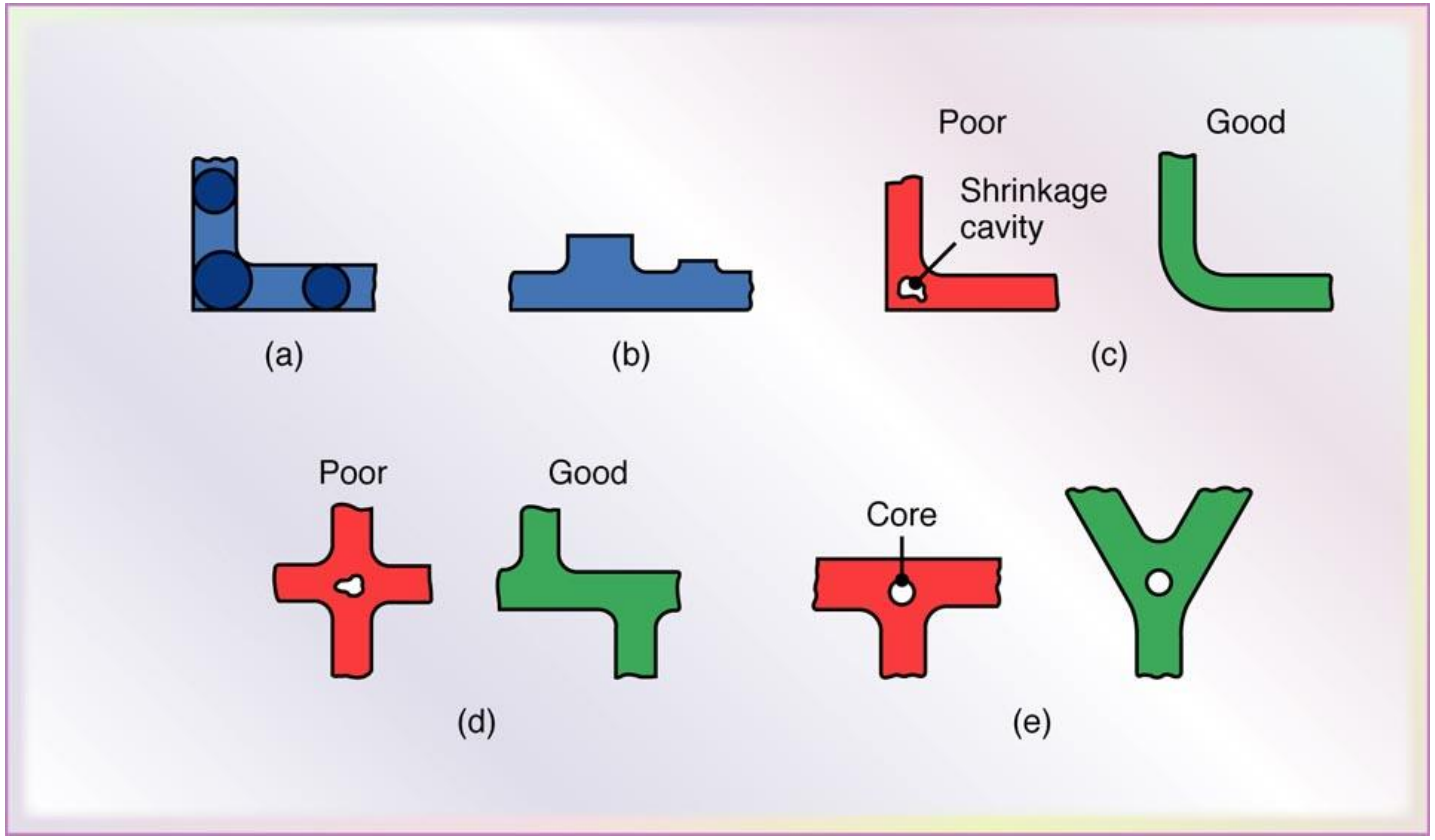
- Design simple part for the ease of casting process.
- Select a casting process and material suitable for the part, size, mechanical properties, etc.
- Position proper parting line of the mold in the part.
- Position and design the best gating system to allow uniform feeding of liquid metals into the mold cavity.
- Select an appropriate runner geometry for the system.
- Position mold features in appropriate way such as sprue, vents and risers.
- Make sure proper controls and good practices are applied.

General Design Rules for Sand Casting



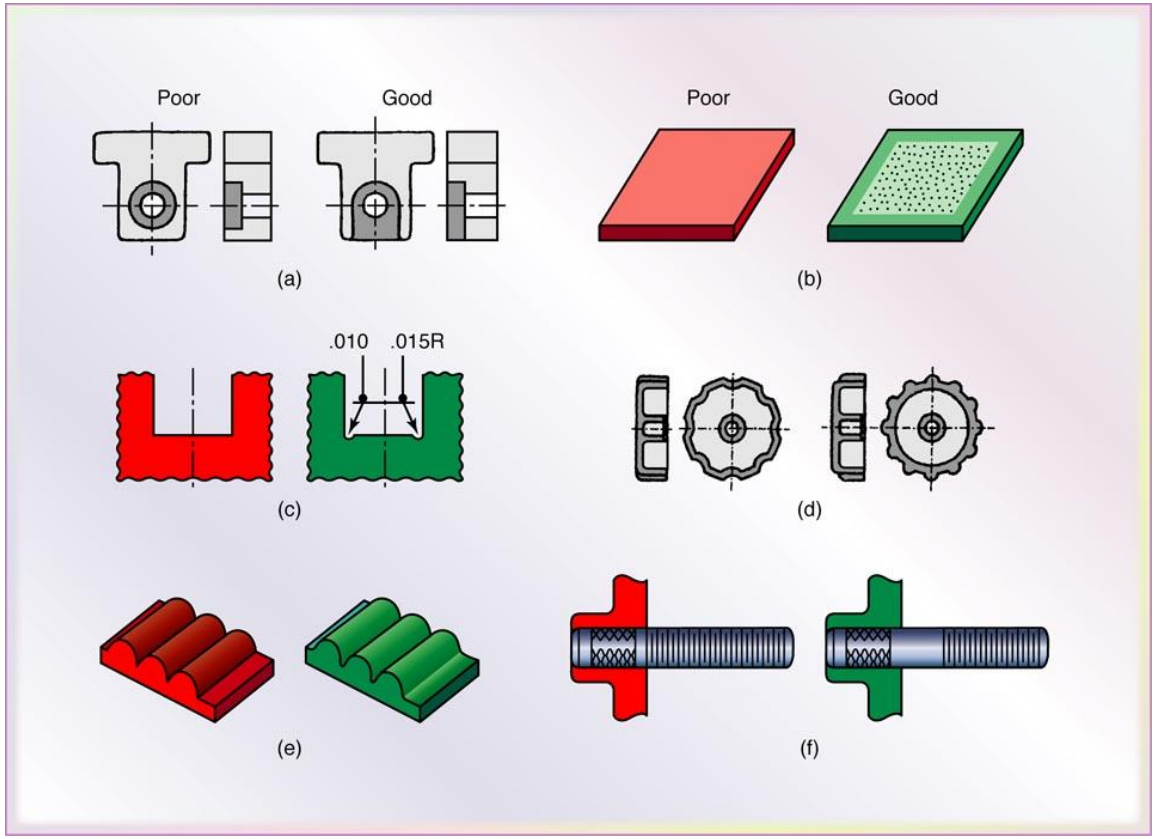
Recommended design modifications to overcome defects in castings. Source by Kalpakjian Book, 2014.

Elimination of Hot Spots



Examples of designs showing the importance of maintaining uniform cross-sections in castings to avoid hot spots and shrinkage cavities. Source by Kalpakjian Book, 20014.

Characteristics of Good and Poor Designs



Characteristics of undesirable (poor) and desirable (good) casting designs. *Source:* Courtesy of American Die Casting Institute.

End of sub-chapter Metal Casting Processes
(Sand Casting)