Department of Mechanical Engineering
GENERAL SIR JOHN KOTELAWALA DEFENCE UNIVERSITY

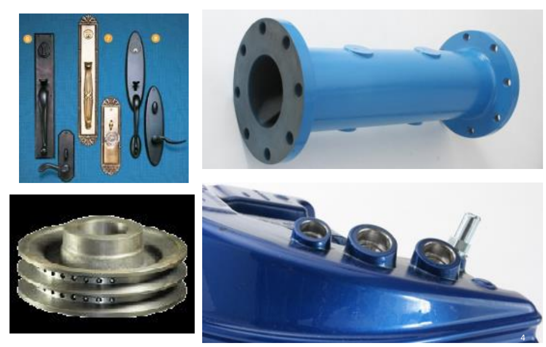
Workshop Technology

Metal Casting

Casting

- It is the oldest Manufacturing Process (4000B.C)
- It is process of pouring molten metal in to a mold cavity of desired shape & size of the part to be produced, allowing it to solidify.
- 33Simple & Some Complex Shapes can be made
  - Ex: Door handles, locks, the outer casing or housing for motors, pumps, vehicle parts, wheels of many cars, planes Structural parts, Machine components, Frames Engine blocks, pipes etc..
- Open Molds - Simple parts
  Closed Molds - Complex parts
  - A passageway - the gating system leading into the cavity

Some of Product



Advanced technology

Advantages of Casting

- Complex geometries – external and internal parts
- Can produce net-shaped or near net-shaped
- Can produce very large parts as well as small
- Any metals can be heated to its liquid phase
- Can used for mass-production
- Can used with automated advance systems

Disadvantages of Casting

- Limitation in mechanical properties, porosity
- Dimensional accuracy, surface finish
- Metals which having Higher melting point require more fuel to melt
- Safety Hazard
- Environmental problems

Casting Processes

1. **Preparing a mold** of the desired shape with proper allowance for shrinkage.

   Parts of the mold

   – The mold cavity - the external surfaces of the cast part. Mold cavity is formed by packing sand around a pattern.

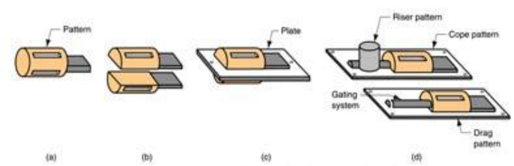
   – The pattern - usually oversized for shrinkage is removed.

   – A core - placed inside the mold cavity to define the interior geometry.

The Pattern

- A full-sized model of the part, slightly enlarged to account for shrinkage and machining allowances in the casting
- Pattern materials:
  - Wood - common material because it is easy to work, but it warps
  - Metal - more expensive to make, but lasts much longer
  - Plastic - compromise between wood and metal

Types of Patterns



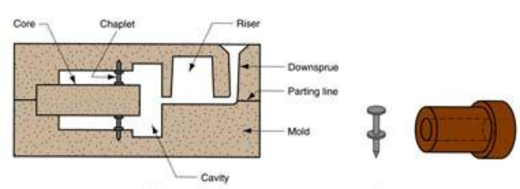
(a) solid pattern
(b) split pattern
(c) match-plate pattern
(d) cope and drag pattern

The Core

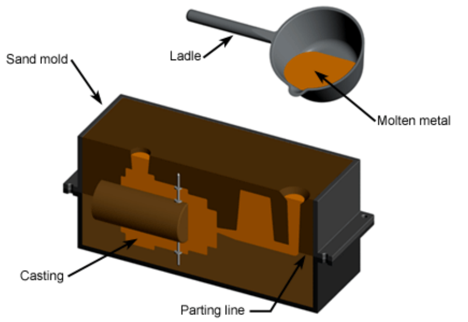
Full-scale model of interior surfaces of part

- It is inserted into the mold cavity prior to pouring the molten metal.
- The molten metal flows and solidifies between the mold cavity and the core to form the casting's external and internal surfaces.
- May require supports to hold it in position in the mold cavity during pouring, called chaplets.

Internal Cavity with Core



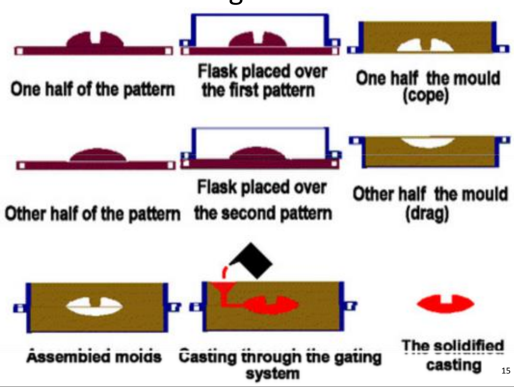
(a) Core held in place in the mold cavity by chaplets
(b) possible chaplet design
(c) casting with internal cavity



Casting Processes

1. **Melting the metal** with acceptable quality & temp.
2. **Pouring the metal into the Cavity** & Providing means for the escape Air or Gases.
3. **Solidification** process must be properly designed & controlled to avoid defects.
4. **Mold removal**.
5. **Finishing**, Cleaning & Inspection.

Casting Processes



Heating & Pouring

- Heat provided must sufficient to melt and raise the molten metal to a right state
- Factors affecting 'pouring'
  - Pouring temperature (melting temp.)
  - Pouring rate
    - Too slow, metal freezes
    - Too high, turbulence
  - Turbulence
    - Accelerate the formation of oxides
    - Mold erosion
    - Voids

Melting Points of Common Metals

Elements	Symbol	Melting Point Celsius	Melting Point Fahrenheit
Aluminum	Al	659	1218
Brass (85 Cu 15 Zn)	Cu+Zn	900-940	1652-1724
Bronze (90 Cu 10 Sn)	Cu+Sn	850-1000	1562-832
Cast Iron	C+Si+Mn+Fe	1260	2300
Carbon	C	3600	6512
Chromium	Cr	1615	3034
Copper	Cu	1083	1981
Gold	Au	1063	1946
Hydrogen	H	-259	-434.2
Inconel	Ni+Cr+Fe	1393	2540
Iron	Fe	1530	2786
Lead	Pb	327	621
Magnesium	Mg	670	1240
Manganese	Mn	1260	2300
Nickel	Ni	1452	2646
Phosphorous	P	44	111
Silicon	Si	1420	2588
Silver	Ag	961	1762
Stainless Steel	Cr+Ni+Mn+C	1363	2550
Steel-High Carbon	Cr+Ni+Mn+C	1353	2500
Medium Carbon	Cr+Ni+Mn+C	1427	2600
Low Carbon	Cr+Ni+Mn+C	1464	2700
Tin	Sn	232	450
Titanium	Ti	1795	3263
Tungsten	W	3000	5432
Zinc	Zn	419	786

- Fluidity: A measure of the capability of a metal to flow into and fill the mold before freezing. (Inverse of viscosity)
  - Factors affecting fluidity -Metal composition, Viscosity, Heat transfer to the surroundings, Heat of fusion and Solidification
  - Pure metals: good fluidity

    Alloys: not as good

Types of casting process

- Casting
  - Expendable mold processes
    - Sand casting
    - Shell Molding
    - Vacuum Molding
    - Expanded Polystyrene Process
    - Investment casting
    - Plaster and Ceramic Mold casting
  - Permanent mold processes
    - Die casting
      - Hot-Chamber Die Casting
      - Cold-Chamber Die Casting
    - Centrifugal casting

Two Main Categories

1. Expendable mold processes

   A mold after process must be destroyed in order to remove casting

   – A new mold is required for each new casting
   – Mold materials: sand, plaster and similar materials + binders
   – More intricate geometries
   – Sand Casting, Shell Molding, Vacuum molding, Expandable Polystyrene, Investment Casting, Plaster Molding, Ceramic Mold Casting

20

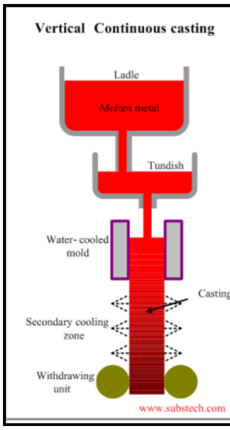
2. Permanent mold processes

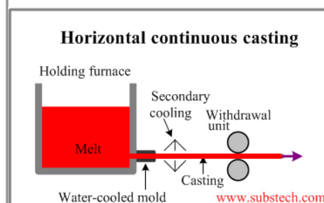
   A mold can be used many times to produce many castings

   – Mold is made of durable materials like, metal and less commonly, a ceramic refractory material
   – Part shapes are limited
   – Permanent mold processes are more economic in high production rate

21

Continuous Casting





22

1. Sand casting

- Most widely used casting process
- Parts ranging in size from small to very large
- Production quantities from one to millions
- Use Patterns and Cores to make mold.
- Sand –
  – Sand with a mixture of water and bonding clay (green sand - "Green" means mold contains moisture at time of pouring)
  – Typical mix: 90% sand, 3% water, and 7% clay to enhance strength and permeability
  – Natural or synthetic sand (lake sand), refractory material called silica (SiO_2)is used for high temperature

23

1. Sand casting

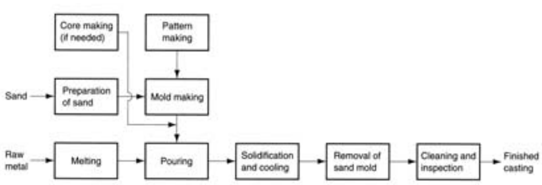
– The sand grains must be small enough so that it can be packed densely
– The grains must be large enough to allow gasses formed during the metal pouring to escape through the pores.
– Molding Sand : Sand, which binds strongly without losing its permeability to air or gases. It is a mixture of silica sand, clay and moisture in appropriate proportions.
– Facing Sand : The small amount of carbonaceous material spread on the inner surface of the mold cavity to give a better surface finish to the castings.
– Backing Sand : it is what constitutes most of the refractory material found in the mould. This is made up of used and burnt sand.

24

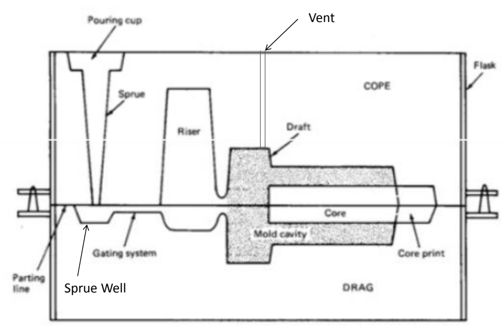
Desirable Mold Properties and Characteristics

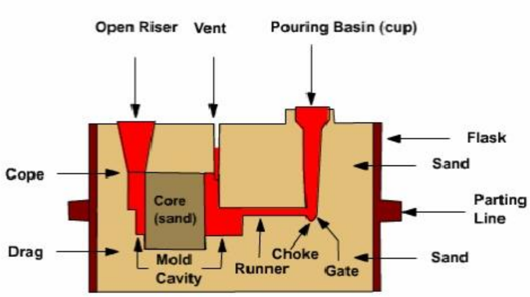
- Strength- to maintain shape and resist erosion
- Permeability- to allow hot air and gases to pass through voids in sand
- Thermal stability- to resist cracking on contact with molten metal
- Collapsibility- ability to give way and allow casting to shrink without cracking the casting
- Reusability- can sand from broken mold be reused to make other molds?

Steps in Sand Casting

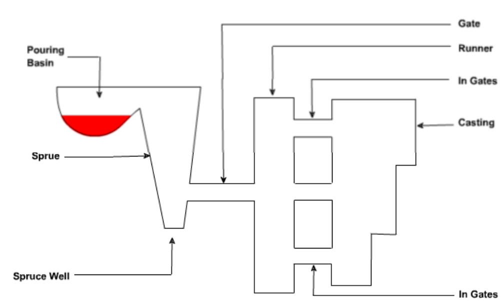


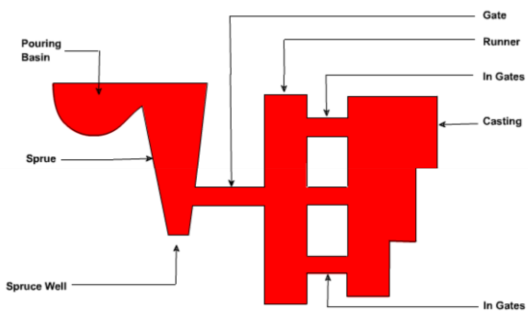
Sand casting terminology





Mold



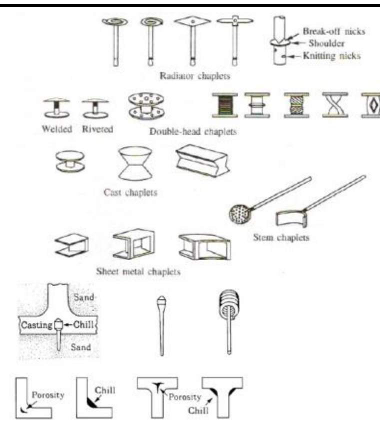


Casting Terms

1. Flask : A metal or wood frame, without fixed top or bottom, in which the mold is formed. Depending upon the position of the flask in the molding structure, it is referred to by various names such as drag - lower molding flask, cope - upper molding flask, cheek – intermediate molding flask used in three piece molding.
2. Pattern : It is the replica of the final object to be made. The mold cavity is made with the help of pattern.
3. Parting Line : This is the dividing line between the two molding flasks that makes up the mold.
4. Bottom Board : This is a board normally made of wood which is used at the start of the mould making. The pattern is first kept on the bottom board, sand is sprinkled on it and then the ramming is done in the drag.
8. Core : A separate part of the mold, made of sand and generally baked, which is used to create openings and various shaped cavities in the castings.
9. Pouring basin : A small funnel shaped cavity at the top of the mold into which the molten metal is poured.

Casting Terms

9. Sprue : The passage through which the molten metal, from the pouring basin, reaches the mold cavity. In many cases it controls the flow of metal into the mold.
10. Sprue Base Well - The curved cavity at the bottom of the sprue helps in reducing the velocity of the incoming metal and also the mould erosion
11. Runner : The channel through which the molten metal is carried from the sprue to the gate.
12. Gate : A channel through which the molten metal enters the mold cavity.
13. Chaplets : Chaplets are used to support the cores inside the mold cavity to take care of its own weight and overcome the metallostatic force.
14. Chill : These are metallic objects which are placed in the mould to increase the cooling rate of castings to provide uniform or desired cooling rate.
15. Riser : A column of molten metal placed in the mold to feed the castings as it shrinks and solidifies. Also known as "feed head".
16. Vent : Small opening in the mold to facilitate escape of air and gases



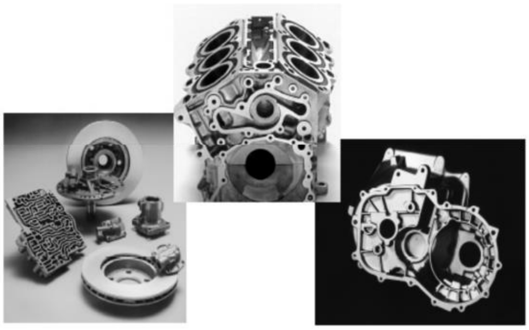
Advantages of Sand casting

- Least Expensive Casting Process
- Castings can be up to Several Tons
- Less Expensive than Machining Shapes from Bar Stock
- Low tooling and equipment cost
- Can Cast Intricate Shapes
- Can be Used with Most Pourable Metals and Alloys
- Scrap can be recycled

Disadvantages of Sand casting

- Additional machining is required
- Not a precision casting process, Poor surface finish and tolerance
- Thin sections are not possible
- High porosity possible
- Low production rate
- High labor cost

Sand Cast Parts



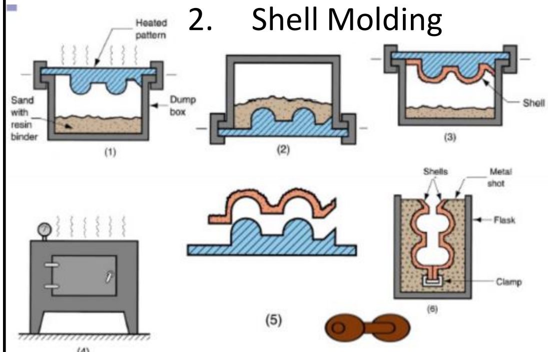
48

Other Expendable Mold Casting

2. Shell Molding
3. Expanded Polystyrene Casting
4. Investment Casting
5. Vacuum Molding
6. Plaster and Ceramic Mold Casting

49

2. Shell Molding



50

Advantages of Shell Molding

- Smoother cavity surface permits easier flow of molten metal and better surface finish
- Good dimensional accuracy
- Machining often not required
- Mold collapsibility minimizes cracks in casting
- Can be used for mass production

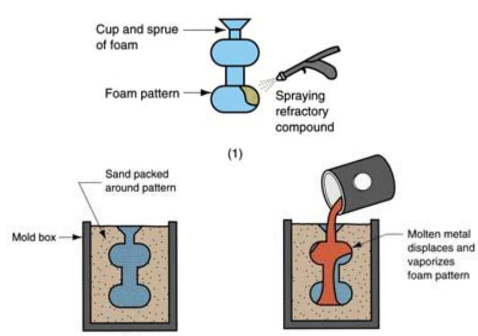
51

Disadvantages of Shell Molding

- More expensive metal pattern
- Difficult to justify for small quantities

52

3. Expanded Polystyrene Casting



53

Advantages of Expanded Polystyrene Casting

– Pattern need not be removed from the mold
– Simplifies and accelerates mold-making, since two mold halves (cope and drag) are not required as in a conventional green-sand mold
– Automated Mass production of castings for automobile engines
– Complex shape can be cast

54

Disadvantages of Expanded Polystyrene Casting

– A new pattern is needed for every casting
– Economic justification of the process is highly dependent on cost of producing patterns

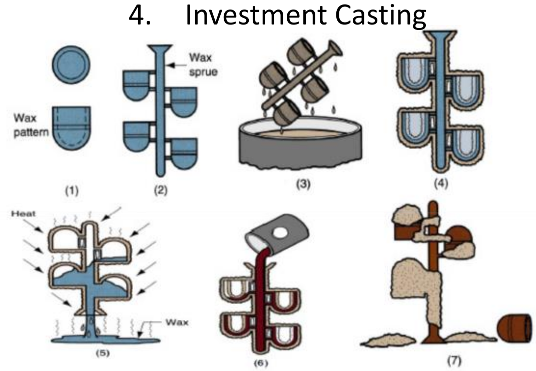
55

4.Investment Casting

- Another name Lost Wax Process
- A pattern made of wax is coated with a refractory material to make mold, after which wax is melted away prior to pouring molten metal.
- "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

56

4. Investment Casting



57

Processing steps

1. The mold is made by making a pattern using wax or some other material that can be melted away.
2. This wax pattern is dipped in refractory slurry, which coats the wax pattern and forms a skin.
3. This is dried and the process of dipping in the slurry and drying is repeated until a robust thickness is achieved.
4. The entire pattern is placed in an oven and the wax is melted away.
5. This leads to a mold that can be filled with the molten metal. Because the mold is formed around a one-piece pattern

58

Advantages of Investment Casting

- Parts of great complexity and intricacy can be cast
- Close dimensional control and good surface finish
- Wax can usually be recovered for reuse
- Additional machining is not required

59

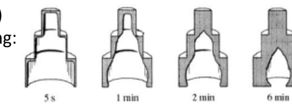
Disadvantages of Investment Casting

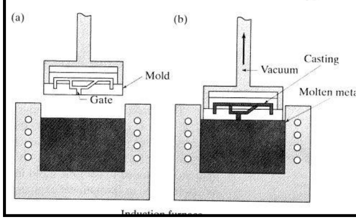
- Many processing steps are required
- Relatively expensive process

60

5. Vacuum Casting

- Fill mold by Vacuuming the mold cavity (reverse gravity)
- Easier to make hollow casting: early pour out





61

Vacuum Casting

62

Advantages of Vacuum Casting

- Good surface finish - Process to precision applications
- Excellent dimensional tolerances
- Flow rate of molten metal into the mold cavity can be accurately controlled
- metal drawn into the mold cavity is from below the surface of the molten metal bath, avoiding slag and inclusions
- It is often easier to automate than gravity pouring

63

Disadvantages of Vacuum Casting

- High cost for equipment & molds.

64

6. Plaster and Ceramic Mold Casting

- Similar to sand casting except mold is made of plaster of Paris (gypsum - $CaSO_4$-$2H_2O$)
- Plaster and water mixture is poured over plastic or metal pattern to make a mold

65

- Ceramic mold casting
  – the slurry is a mixture of fine grained zircon, aluminum oxide, and fused silica, which are mixed with bonding agents and poured over the pattern, which has been placed in a flask
  – because of the high temperature resistance, these molds can be used in casting ferrous and other high temperature alloys

Advantages of Plaster Molding

– Good dimensional accuracy and surface finish

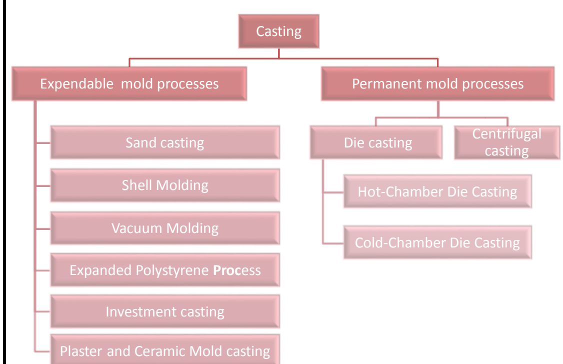
– Capability to make thin cross-sections in casting

Disadvantages of Plaster Molding

– Moisture in plaster mold causes problems:
  - *Mold must be baked to remove moisture*
  - *Mold strength is lost when is over-baked, yet moisture content can cause defects in product*

– Plaster molds cannot stand high temperatures

Types of casting process



Permanent Mold Casting

- In permanent mold casting, the mold is reused many times

- The processes include:
  Basic permanent mold casting
  Die casting
  Centrifugal casting

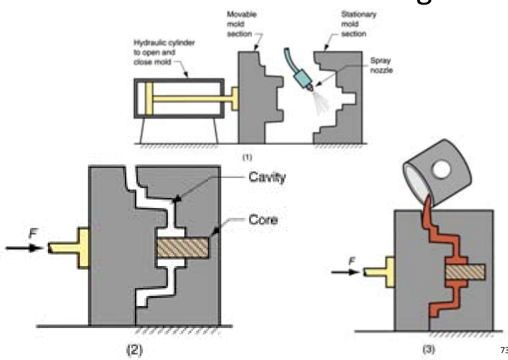
Permanent Mold Casting

- Metals - Al, Mg, Copper alloy and Cast Iron (Low MP metals)

- Basic Steps
  – Preheated Mold (metals to flow)
  – Coatings are sprayed
  – Pour and solidify
  – Mold is open and casting is removed

- Example
  – Automobile piston, pump bodies castings for aircraft and missiles

Permanent mold casting



73

Advantages of Permanent Mold Casting

- Good surface finish and dimensional control
- Fine grain due to rapid solidification
- So stronger castings are produced

74

Disadvantages of Permanent Mold Casting

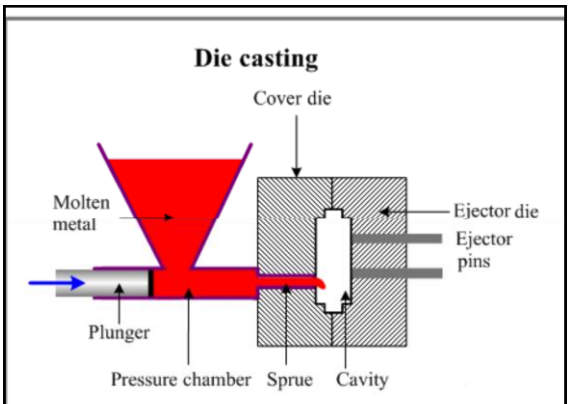
- Only for Simple geometric part because of the need to open the mold
- Expensive mold
- Generally limited to metals of lower melting point

75

Die casting

- A permanent mold casting process in which molten metal is injected into mold cavity (die) under **high pressure** (7-350MPa)
- Pressure is maintained during solidification, then mold is opened and part is removed

76



- Very commonly used type of permanent mold casting process.
- Good Surface finish & tolerance
- Die casting molds are expensive, and require significant time to fabricate; they are commonly called dies.

78

- Molds are made of tool steel, mold steel, tungsten and molybdenum
- Single or multiple cavity
- Lubricants and Ejector pins to free the parts
- Venting holes and passageways in die
- Formation of flash that needs to be trimmed

Advantages of Die casting

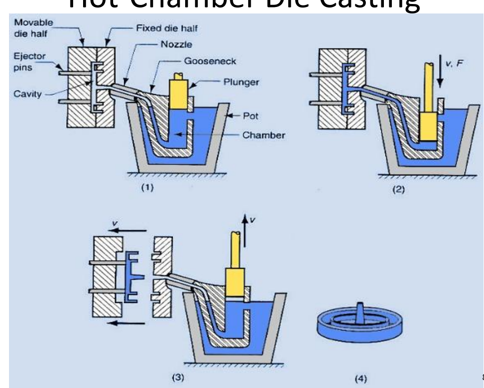
- Economical for large production quantities
- Good accuracy and surface finish
- Thin sections are possible
- Rapid cooling provides small grain size and good strength to casting

Disadvantages of Die casting

- Generally limited to metals with low melting points
- Part geometry must allow removal from die
- Used for producing many components of home appliances

Examples: rice cookers, stoves, fans, washing & drying machines, fridges, motors, toys & hand-tools

Hot-Chamber Die Casting

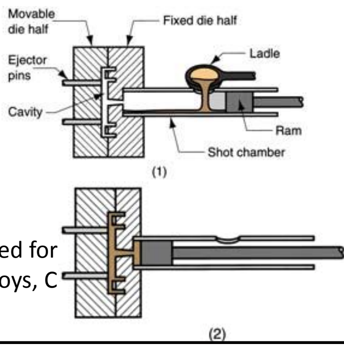


HOT CHAMBER: (low mp e.g. Zn, Pb; non-alloying)

- Die is closed, gooseneck cylinder is filled with molten metal
- Plunger pushes molten metal through gooseneck into cavity
- Metal is held under pressure until it solidifies
- Die opens, cores retracted; plunger returns
- Ejector pins push casting out of ejector die

- A gooseneck is partially submerged in a reservoir of molten metal.
- To begin the cycle, molten metal flows through as open port to fill the gooseneck.
- A mechanical plunger or air-injection system then forces the metal out of the gooseneck and into the die, where it rapidly solidifies.
- Hot chamber die casting offers fast cycling times (up to about 15 cycles per minute)
- Advantage that the molten metal is injected from the same chamber in which it is melted (i.e. there is no handling or transfer of molten metal).
- Hot chamber design cannot be used for the higher melting point metals and it is unattractive for aluminum since there is a tendency for molten aluminum to pack up some iron as a result of the extended time in contact with the casting equipment.

Cold-Chamber Die Casting



used for alloys, C … um

COLD CHAMBER: (high mp e.g. Cu, Al)

- Die closed, molten metal is ladled into cylinder
- Plunger pushes molten metal into die cavity
- Metal is held under high pressure until it solidifies
- Die opens, plunger pushes solidified slug from the cylinder
- Cores retracted
- Ejector pins push casting off ejector die

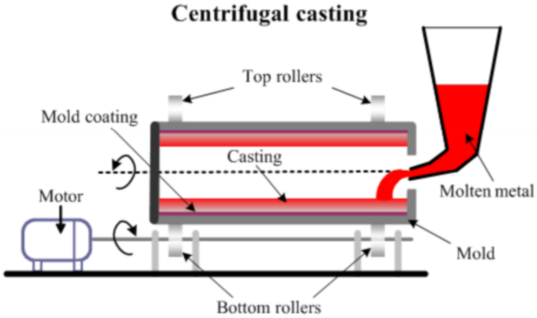
Melting point of common materials

Metal Alloy Type	Temp Range (Celsius)
1. Zinc	345-455
2. Aluminum	620-735
3. Magnesium	620-735
4. Copper	908-1180
5. Cast Irons	1340-1480
6. High Manganese Steel	1400-1455
7. Nickel Based Super Alloys	1430-1540
8. High Alloy Steels	1480-1600
9. High Alloy Irons	1540-1650
10. Carbon & Low Alloy Steel	1565-1700
11. Titanium	1700-1820
12. Zirconium	1845-1900

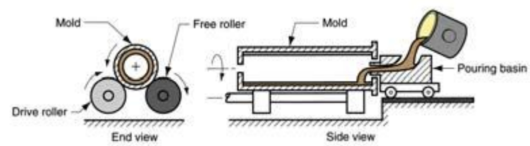
- Usually employed for the die casting of materials that are not suitable for the Hot chamber design.
  - Alloys of aluminum, magnesium, copper, and high aluminum zinc.
- Metal is melted in a separate furnace.
- Transfer the metal to the die casting machine, where a measured quantity is fed into an unheated short chamber (or injection cylinder)
- Subsequently driven into the die by hydraulic or mechanical plunger.
- The pressure then maintained or increased during solidification.
- Since molten metal must be transferred to the chamber for each cycle, the cold chamber process has longer operating cycle than that of the hot chambers machines.

Die Casting Part Example

Centrifugal casting



Centrifugal casting



Centrifugal casting

- Method of casting parts having axial symmetry
- The method involves pouring molten metal into a cylindrical mold spinning about its axis of symmetry
- The mold is kept rotating till the metal has solidified
- The mold material steels, Cast irons, Graphite or sand may be used
- The rotation speed of is about 1000 RPM

Different Casting Processes

Process	Advantages	Disadvantages	Examples
1.Sand	many metals, sizes, shapes, cheap	poor finish & tolerance	engine blocks, cylinder heads
2.Shell mold	better accuracy, finish, higher production rate	limited part size	connecting rods, gear housings
3.Expandable pattern	Wide range of metals, sizes, shapes	patterns have low strength	cylinder heads, brake components
4.Plaster mold	complex shapes, good surface finish	non-ferrous metals, low production rate	prototypes of mechanical parts
5.Ceramic mold	complex shapes, high accuracy, good finish	small sizes	impellers, injection mold tooling
6.Investment	complex shapes, excellent finish	small parts, expensive	jewellery
7.Permanent mold	good finish, low porosity, high production rate	Costly mold, simpler shapes only	gears, gear housings
8.Die	Excellent dimensional accuracy, high production rate	costly dies, small parts, non-ferrous metals	gears, camera bodies, car wheels
9.Centrifugal	Large cylindrical parts, good quality	Expensive, few shapes	pipes, boilers, flywheels

Casting Defects

- Any unwanted deviation from the desired requirements in a cast product results in a defect. Some defects in the cast products are tolerable while others can be rectified by additional processes like welding etc. The following are the major defects which are likely to occur in sand casting:

1. Gas defects
2. Shrinkage cavities
3. Molding material defects
4. Pouring metal defects
5. Metallurgical defects

1. Gas Defects

- Gas defects are due to lower gas passing tendency of the mould which is caused by, lower venting
  lower permeability of the mould and
  improper design of the casting
- The lower permeability of the mould is due to,
  use of finer size grains of sand
  higher percentage of clay &
  moisture and excessive ramming of the mould

The various gas defects

- **Blow holes and Open blows:**
- **Scar**
- **Blister**
- **Air inclusions**
- **Pin hole porosity**

The various gas defects are discussed here in detail.

- **Blow holes and Open blows:**


Blow

- These are spherical, flattened or elongated cavities present inside the casting or on the surface. When present inside the casting it is called blow hole while it is termed as open blow if it appears on the surface of the casting. These defects are caused by the moisture left in the mould and the core. Due to heat of the molten metal the moisture is converted into steam, part of which when entrapped in the casting ends up as blow hole or ends up as open blow when it reaches the surface. Thus in green sand mould it is very difficult to get rid of the blow holes, unless properly vented.

- **Scar:**


Scar

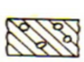
A shallow blow, usually found on a flat casting surface, is referred to as a scar.

- **Blister:**


Blister

This is a scar covered by the thin layers of a metal.

- **Air inclusions:**


Gas holes

- The atmospheric and other gases absorbed by the molten metal in the furnace, in the ladle and during the flow in the mould, when not allowed to escape, would be trapped inside the casting and weaken it. The main reasons for this defect are the higher pouring temperatures which increase the amount of gas absorbed; poor gating design such as straight sprue in unpressurised gating; abrupt bends and other turbulence causing practices in the gating, which increase the air aspiration and finally the low permeability of the mould. The remedies would be to choose the appropriate pouring temperature and improve gating practices by reducing the turbulence.

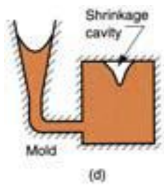
- **Pin hole porosity:**


Pin holes

- As the molten metal gets solidified it loses the temperature which decreases the solubility of gases and thereby expelling the dissolved gases. The hydrogen which is picked up by the molten metal either in the furnace from the unburnt fuel or by the dissociation of water inside the mould cavity may escape the solidifying metal leaving behind very small diameter and long pin holes showing the path of escape. The high pouring temperature which increases the gas pick up is the main reason for this defect.

2. Shrinkage Cavities

- These are caused by the liquid shrinkage occurring during the solidification of the casting. An improper riser and gating system may give this type of defect which has a shape of a funnel.

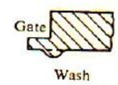


3. Moulding Material Defects

- These defects are originated due to some specific characteristics of the moulding materials like insufficient strength, improper ramming etc.
- **Cuts and Washes**
- **Metal Penetration**
- **Fusion**
- **Run out**
- **Buckles**

- **Rat tail**
- **Scab**
- **Swell**
- **Drop**
- **Dross**
- **Dirt**
- **Mould and Core shift**

- **Cuts and Washes:**



- Theses appear as rough spots and areas of excess metal and are caused by the erosion of the moulding sand by the flowing molten metal. This may be due to insufficient strength of mould material or the high velocity of the molten metal. The proper choice of moulding sand and appropriate moulding method together with better design of gating system which reduces turbulence by increasing the size of the gates or by using multiple ingates can eliminate these defects.

- **Metal Penetration:**

- When molten metal enters the gaps between the sand grains, the result would be a rough casting surface. This is due to either use of coarse sand grains in mold material or nose of mold wash. This can also be caused by higher pouring temperature. Choosing appropriate grain sizes, together with proper mold wash should be able to eliminate this defect.

- **Fusion:** This is caused by the fusion of sand grains with molten metal, giving a brittle, glassy appearance on the casting surface. The main reasons for this defect are the lower refractoriness of the clay used in molding sand and very high pouring temperature. The choice of an appropriate type and amount of Bentonite would cure this defect.
- **Run out:** This is happened when the molten metal leaks out of the mold due to faulty mold making or defective molding flask.

- **Buckles:**

Buckle

- This refers to a long, fairly shallow, broad, v-shaped depression occurring in the surface of a flat casting of a high temperature metal. At this high temperature, an expansion of the thin layer of sand at the mold face takes place before the liquid metal at the mold face solidifies. As this expansion is obstructed by the flask, the mold face tends to bulge out, forming the v shape. A proper amount of volatile additives in the sand-mix is therefore essential to make room for this expansion and to avoid the buckles.

- **Rat tail:**

Rat tail

- It is a long shallow angular depression normally found in a thin casting. The reason for its formation is the same as that of buckles. Here, instead of the expanding sand upheaving, the compressed layer fails by one layer, gliding over the other.

- **Scab:**

Scab

- This refers to the rough thin layer of a metal, protruding above the casting surface, on top of a thin layer of sand. The layer is held onto the casting by a metal stringer through the sand. A scab results when the upheaved sand is separated from the mold surface and the liquid metal flows into the space between the mold and the displaced sand.

- **Swell:**

Swell

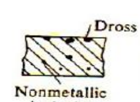
- Under the influence of metallostatic forces, the mold wall may move back causing a swell in the dimensions of the casting. As a result of the swell, the feeding requirements of the casting increase which should be taken care of by the proper choice of riser. The main cause of this defect is improper ramming of the mold.

- **Drop:**

Drop

- An irregularly shaped projection on the cope surface of a casting is called a drop. This is caused by dropping of sand from the cope or other overhanging projections into the mould. An adequate strength of the sand and the use of gaggers can help in avoiding the drops.

- **Dross:**

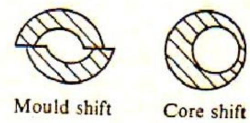


- Lighter impurities appearing on the top of a casting are called dross. It can be taken care of at the pouring stage by using items such as a strainer and skim bob.

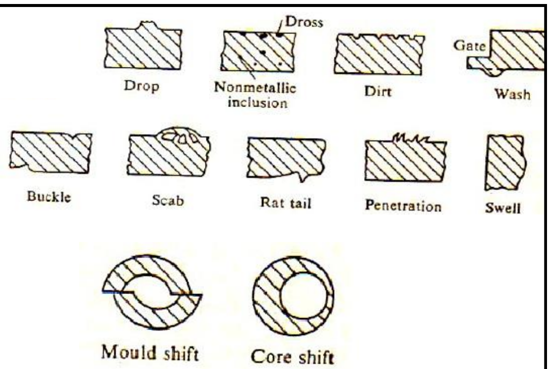
- **Dirt:**

- Sometimes sand particles dropping out of the cope get embedded on the top surface of a casting. When removed, these leave small, angular holes, known as dirt.

- **Mould and Core shift:**



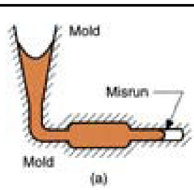
- A misalignment between two halves of a mold or of a core may give rise to a defective casting



4. Pouring Metal Defects

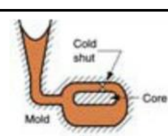
- The likely defects under this category are mentioned here.
  - **Misrun**
  - **Cold shut**
  - **Slag inclusions**

- **Misrun:**



- Many a time, the liquid metal may, due to insufficient superheat, start freezing before reaching the farthest point of the mould cavity. This defect is called Misrun. Typical causes include, Fluidity of the molten metal is insufficient, Pouring Temperature is too low, Pouring is done too slowly and/or Cross section of the mold cavity is too thin.

- **Cold shut:**



- For a casting with gates at its two sides, the misrun may show up at the centre of the casting due to non fusion of two streams of metal resulting in a discontinuity or weak spot in casting. Above two defects are due to lower fluidity of the molten metal or small thickness of the casting. The fluidity of the metal can be increased by changing the composition of molten metal or raising the pouring temperature. The other causes for these defects are large surface area to volume ratio of the casting, high heat transfer rate of the mould material and back pressure of the gases entrapped in the mould cavity due to inadequate venting.

- **Slag inclusions:** During the melting process, flux is added to remove the undesirable oxides and impurities (refractory materials, sand) present in the metal. At the time of tapping, the slag should be properly removed from the ladle, before the metal is poured into the mould. Otherwise any slag entering the mould cavity will be weakening the casting and also spoiling the surface of the casting

5. Metallurgical Defects

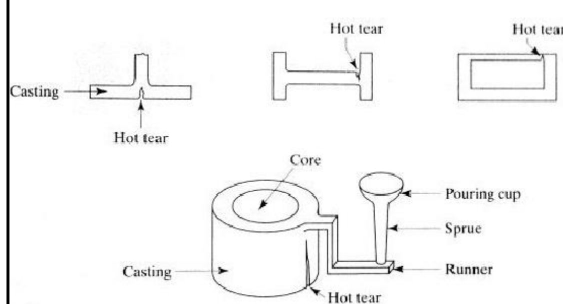
- The defects under this category are hot tears and hard spots.
  - **Hot tears**
  - **Hard spots**

- **Hot tears:**

Since metal has low strength at higher temperatures, any unwanted cooling stress may cause the rupture of the casting. The better design of casting avoids this defect

- **Hard spots:**

These are caused by the chilling of the casting. For example, with grey cast iron having small amounts of silicon, very hard white cast iron may result at the chilled surface. This hard spot will interfere with subsequent machining of this region. Proper metallurgical control and chilling practices are essential for eliminating the hard spots. The remedies of some defects are also causes of others. Therefore one has to analyze the casting from the viewpoint of its final application and thus arrive at a proper moulding procedure to eliminate or minimize the most undesirable casting defects



Porosity / Shrinkage Solutions

- Risers allow molten metal to flow into mold to make up for shrinkage
- Design flow so no part freezes early large channels
- "Flexible" molds
- Allow metal to shrink, not hold metal
- Heating or cooling
- Certain areas to maintain uniform cooling (thermit or chills)
- Uniform part thickness leads to uniform cooling, less residual stress

Table 13.1.2 Design and Cost Features of Basic Casting Methods

Design and cost features	Process: Sand casting	Shell-mold casting	Permanent-mold casting	Plaster-mold casting	Investment casting	Die casting
Choice of materials	Wide—ferrous and nonferrous	Wide—except for low-carbon steels	Restricted—brass, bronze, aluminum, some gray iron	Narrow—brass, bronze, aluminum	Wide—includes hard-to-forge and machine materials	Narrow—zinc, aluminum, brass, magnesium
Complexity	Considerable	Moderate	Moderate	Considerable	Greatest	Considerable
Size range	Great	Limited	Moderate	Moderate	Moderate	Moderate
Minimum section, in	3/32	1/16	0.100	0.010	0.010	0.025
Tolerances, in ft*	1/16–1/8	1/32–3/32	1/32–7/64	1/32–5/64	0.003–0.006	1/32–1/16
Surface smoothness, μin, rms	250–300	150–200	90–125	90–125	90–125	60–125
Design feature remarks	Basic casting method of industry	Considered to be good low-cost casting method	Production economics with substantial quantities	Little finishing required	Best for parts too complicated for other casting methods	Most economical where applicable
Tool and die costs	Low	Low to moderate	Medium	Medium	Low to moderate	High
Optimum lot size	Wide—range from few pieces to huge quantities	More required than sand castings	Best when requirements are in thousands	From one to several hundred	Wide—but best for small quantities	Substantial quantities requird
Direct labor costs	High	Moderate	Moderate	High	Very high	Low to medium
Finishing costs	High	Low	Low to moderate	Low	Low	Low
Scrap costs	Moderate	Low	Low	Low	Low	Low

* Closer at extra cost.
Source: Cook, "Engineered Castings," McGraw-Hill.