MANUFACTURING TECHNOLOGY

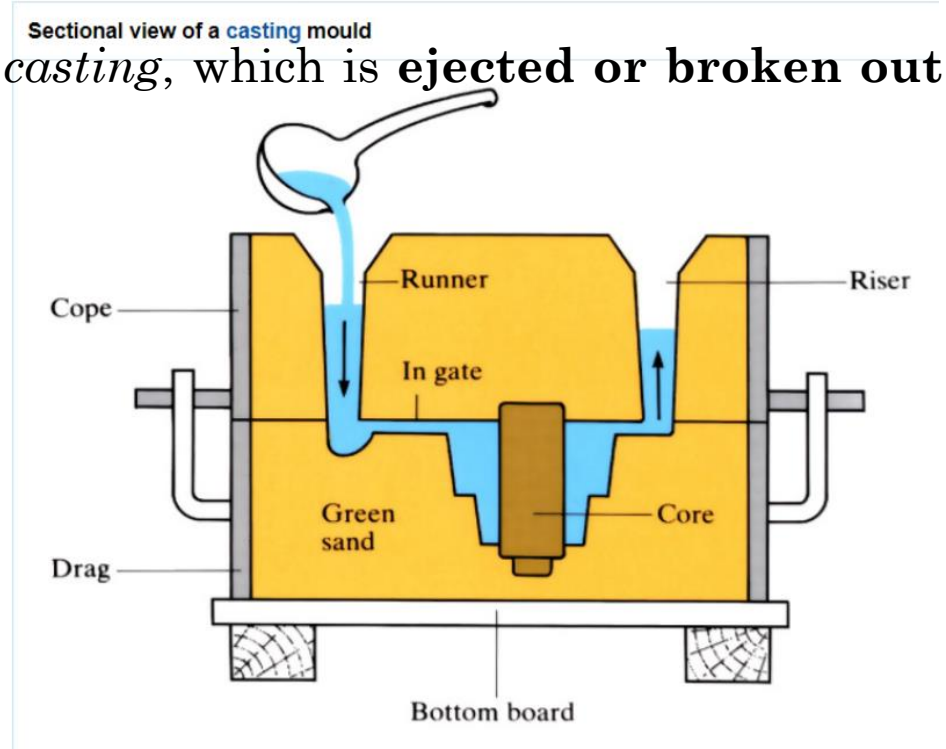
INTRODUCTION TO CASTING

Overview

- ***Introduction to Casting***
- *Casting Procedures*
- *Casting Nomenclature*
- *Making of Sand casting, Gating and Risering system*
- ***Special Casting Process***
- *Expandable Mold Casting*
  - *Shell Mold Casting*
  - *Investment Casting*
- *Permanent Mold Casting,*
  - *Die Casting*
  - *Centrifugal Casting*
- *Casting Defects*

What is Casting?

- **Casting** is a manufacturing process in which a **liquid material (molten metal)** is poured into a mold, which contains **a hollow cavity** of the **desired shape**, and then allowed to solidify.
- The solidified part is known as a *casting*, which is **ejected or broken out** of the mold to complete the process.



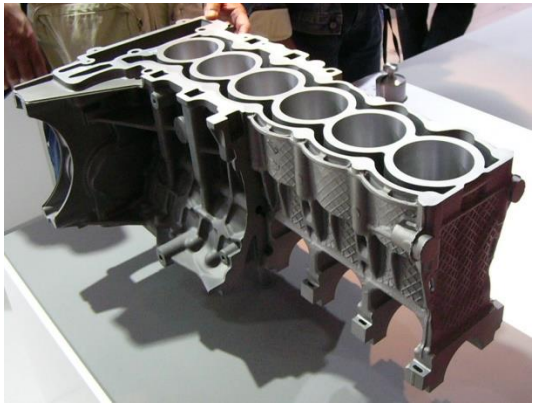
- **Casting Procedure**

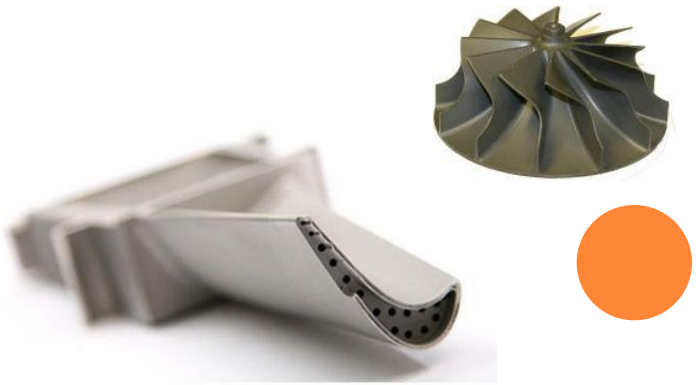
Advantages

- Molten material can flow into very small sections so that **intricate shapes can be made** by this process. (many other operations, such as **machining, forging, and welding**, can be **minimized**).
- Possible to cast practically any material: **ferrous or non-ferrous**.
- The **tools required** for casting moulds are very **simple** and **inexpensive**. As a result, for **production of a small lot**, it is the ideal process.
- Certain parts (**like turbine blades**) made from metals and alloys that can only be processed this way. **Turbine blades:** Fully casting + Final machining.
- **Size and weight** of the product is not a limitation for the casting process.

Limitation:

- **Dimensional accuracy and surface finish** of the castings made by sand casting processes.





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Casting Procedure

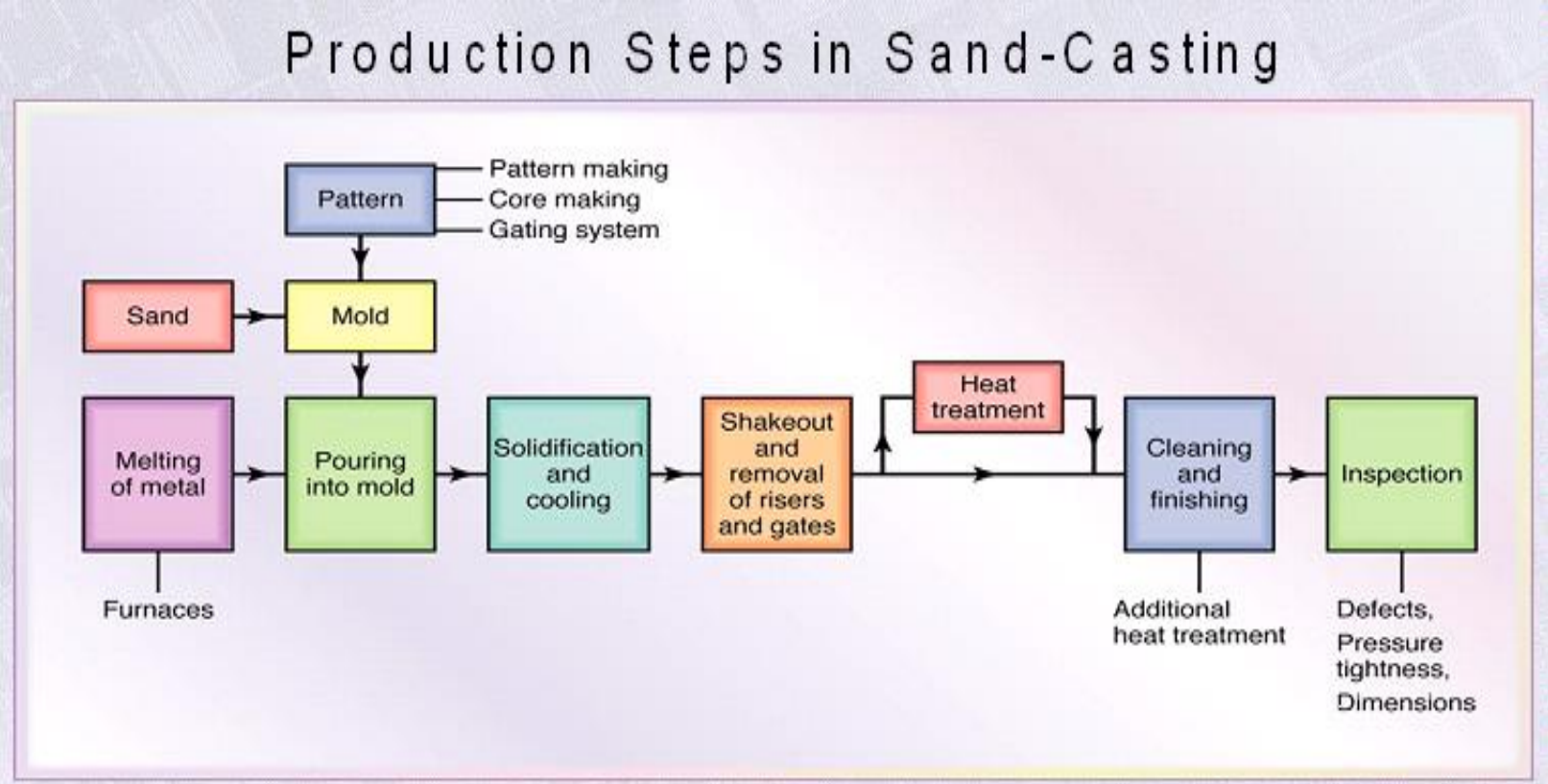

Figure 11.2 Outline of production steps in a typical sand-casting operation.

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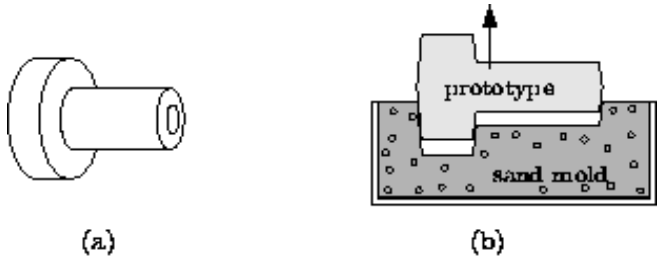
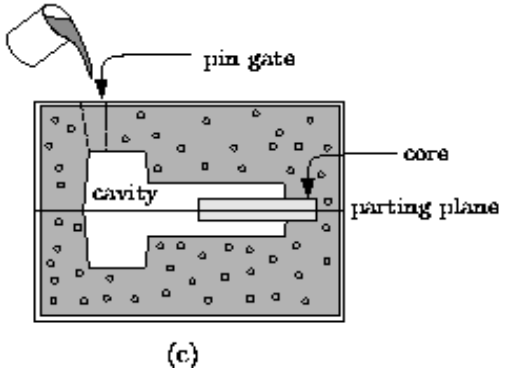
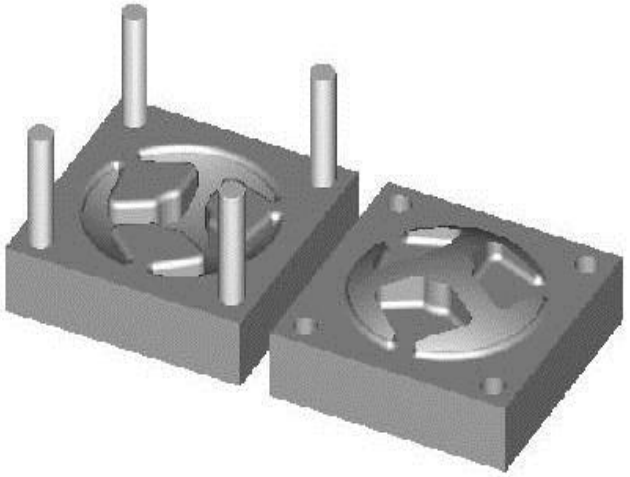
The Casting Process Today





Sand Casting

Sand casting, also known as sand molded casting, is a **metal casting process** characterized by **using sand as the mold material**.

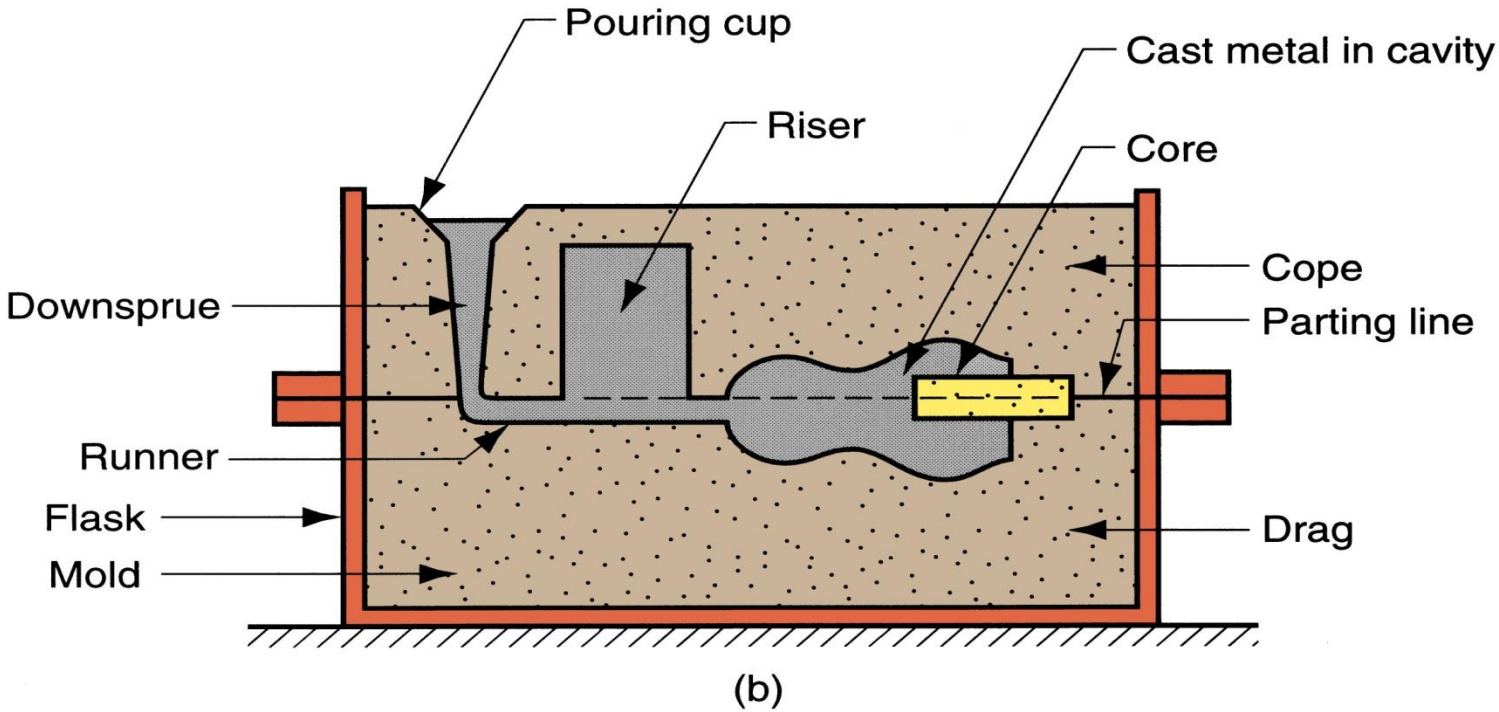


Die Casting

Die casting is a metal casting process that is characterized by forcing molten metal under **high pressure** into a mold cavity.

The mold cavity is created using two **hardened tool steel dies** which have been machined into **desired shape**.

Casting nomenclature



(b)

The pouring cup, down sprue, runners, etc., are known as the *mold gating system*, which serves to deliver the molten metal to all sections of the mold cavity.

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Casting Terms

- Flask: A **metal or wooden frame**, without fixed top or bottom, in which the mold is formed. Depending upon the **position of the flask** in the molding structure
  - drag - lower molding flask
  - cope - upper molding flask
  - cheek - intermediate molding flask used in three piece molding.
- Pattern: It is the **replica of the final product** to be made. The mold cavity is made with the help of pattern.

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- Parting line: This is the **dividing line between the two molding flasks** that makes up the mold.
- 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 sprinkled** on the inner surface of the mold cavity to give a better surface finish to the castings.

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- Core: A **separate part** of the mold, made of sand **(ceramic)** and generally baked, which is used to **create openings and various shaped cavities** in the castings.
- Pouring basin: A small **funnel shaped cavity** at the top of the mold into which the molten metal is poured.
- 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.
- Gate: A channel through which the molten metal enters the mold cavity.

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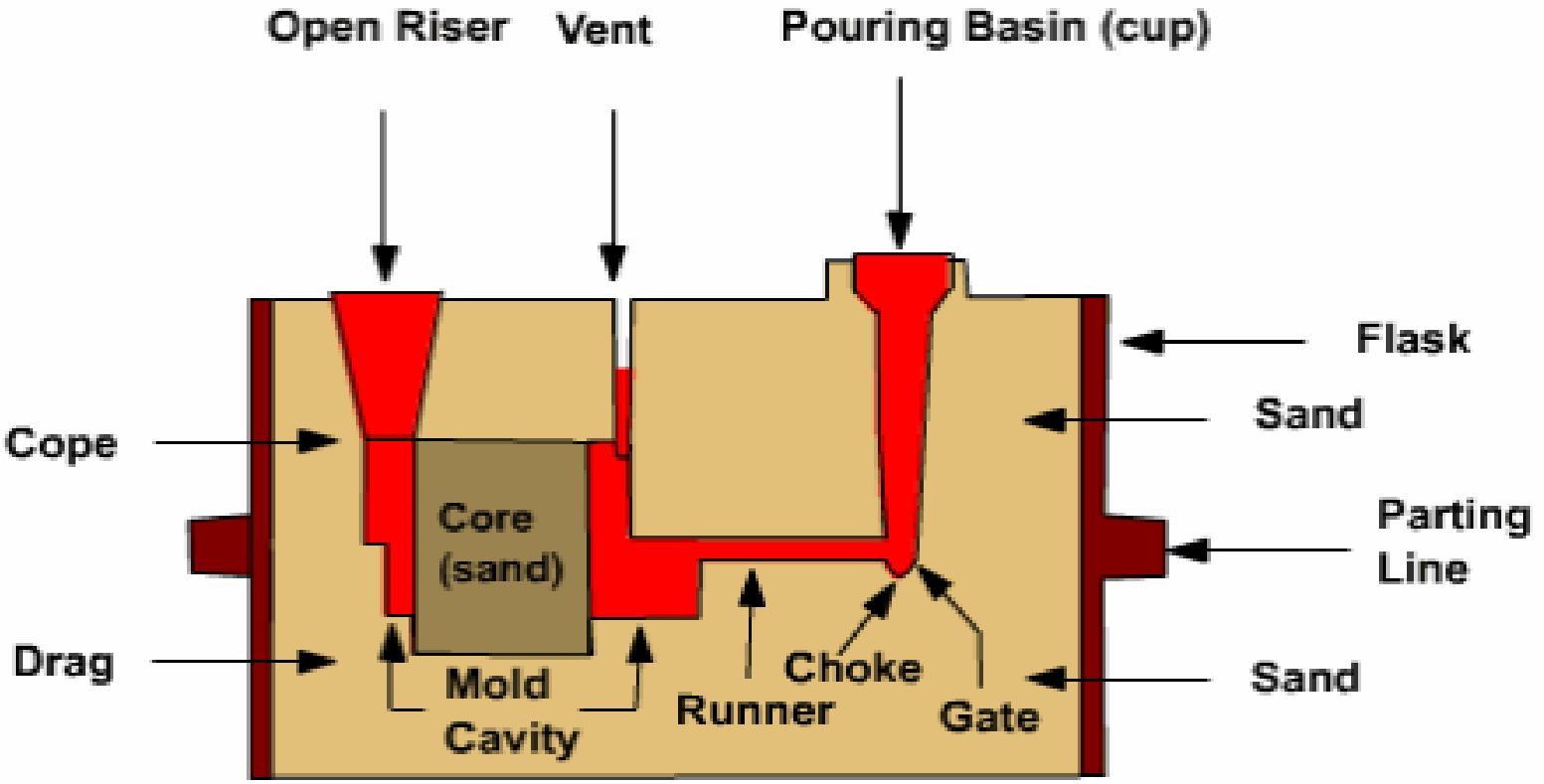
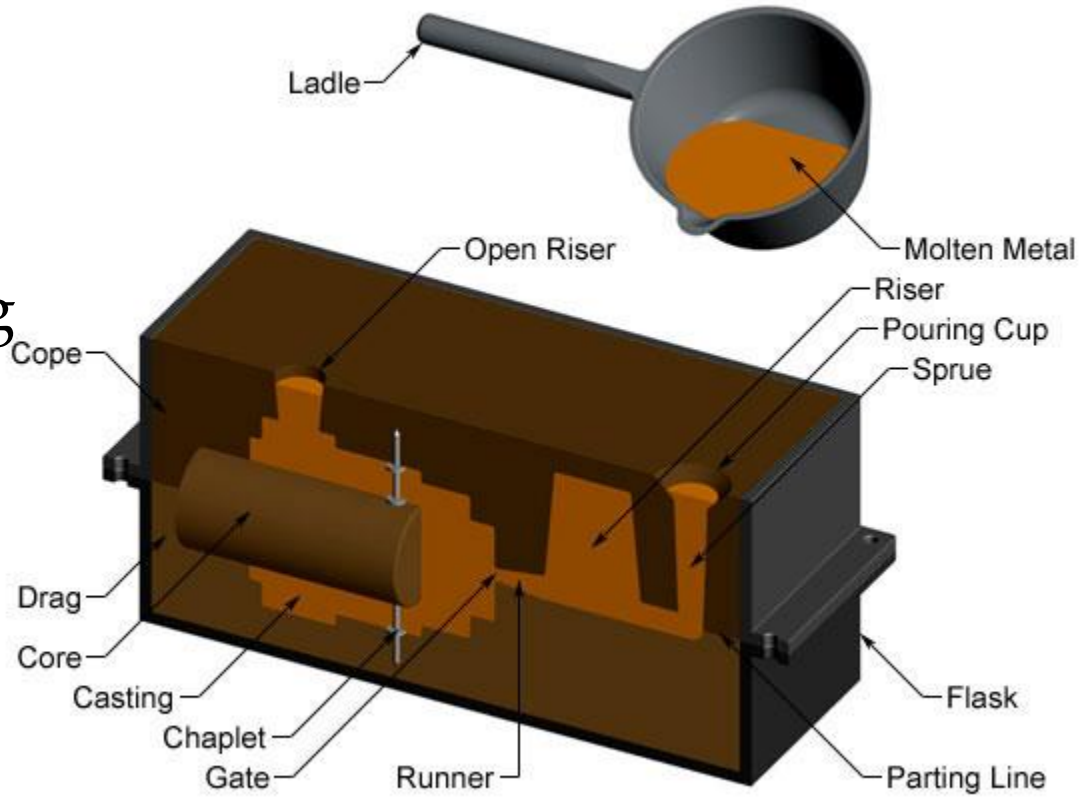
- Runner: The **channel** through which the molten metal is carried from the **sprue to the gate**.
- Chaplets: Chaplets are used to **support the cores** inside the mold cavity to take care of its **own weight** and overcome the **metallostatic force**.
- Riser: A column of molten metal placed in the mold to **feed the castings** as it shrinks and solidifies. Also known as "**feed head**".
- Vent: Small opening in the mold to facilitate **escape of air and gases**.

Mold Section showing some casting terms



Steps in Making Sand Castings

- There are six basic steps in making sand castings:
  - Pattern making
  - Core making
  - Molding
  - Melting and pouring
  - Cleaning



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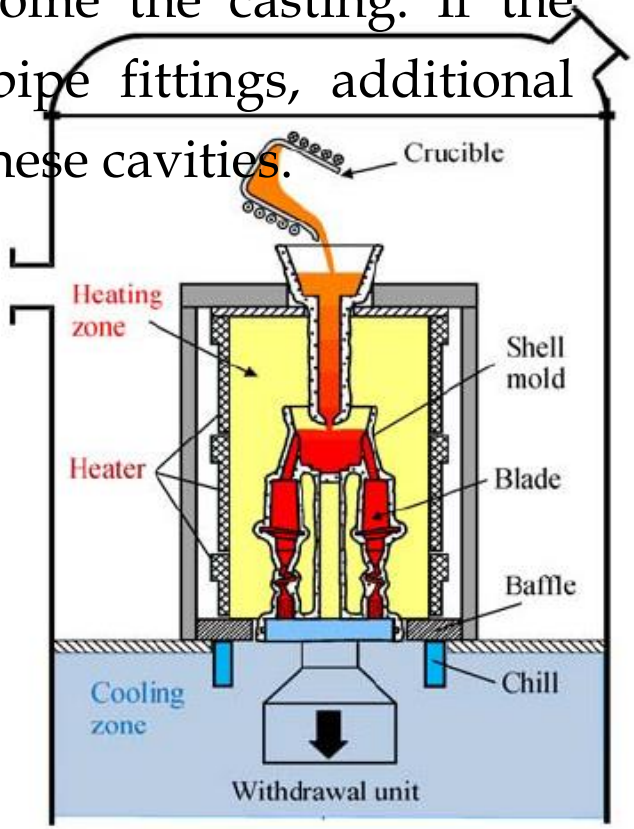
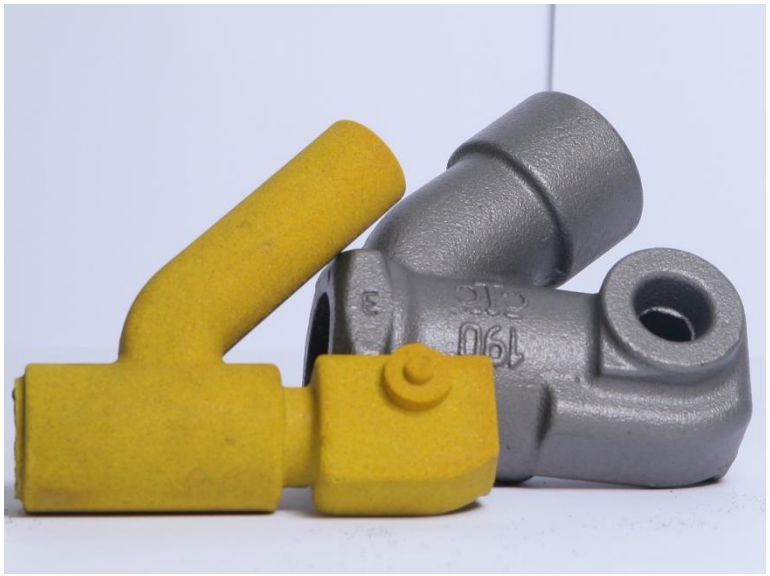
Pattern making

- The pattern is a **physical model of the casting** used to make the mold.
- The mold is made by **packing some readily formed aggregate material**, such as molding sand, around the pattern.
- When the pattern is withdrawn, its imprint provides the mold cavity, which **is ultimately filled with metal** to become the casting. If the **casting is to be hollow**, as in the case of pipe fittings, additional patterns, **referred to as cores**, are used to form these cavities.



Core making

- Cores are forms, **usually made of sand**, which are placed into a mold cavity to form the **interior surfaces** of castings. Thus the **void space between the core and mold-cavity** surface is what eventually becomes the casting.



Molding

- Molding consists of all operations necessary to prepare a **mold for receiving molten metal**.
- Molding usually involves placing a **molding aggregate around a pattern** held with a supporting frame.
- Withdrawing the pattern to leave the mold cavity, **setting the cores in the mold cavity** and finishing and closing the mold.

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Melting and Pouring

- The preparation of **molten metal for casting** is referred to simply as **melting**.
- Melting is usually done in a specifically designated area of the foundry, and the **molten metal is transferred to the pouring area** where the molds are filled.

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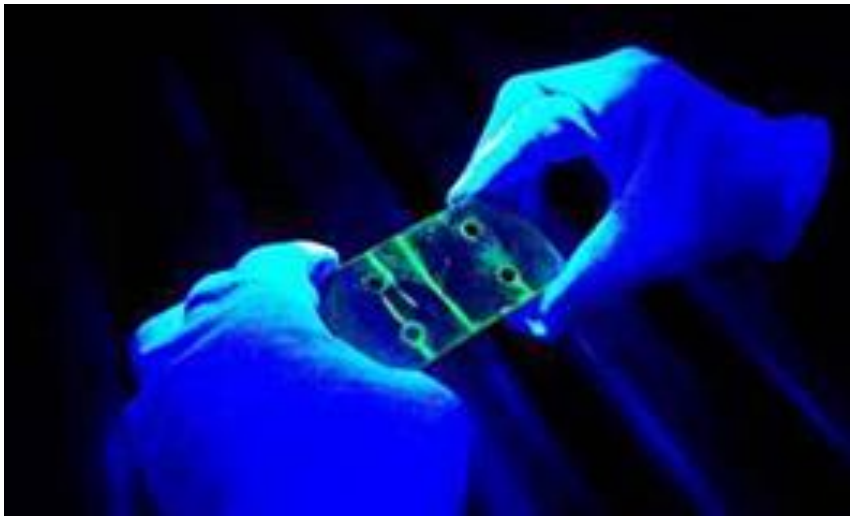
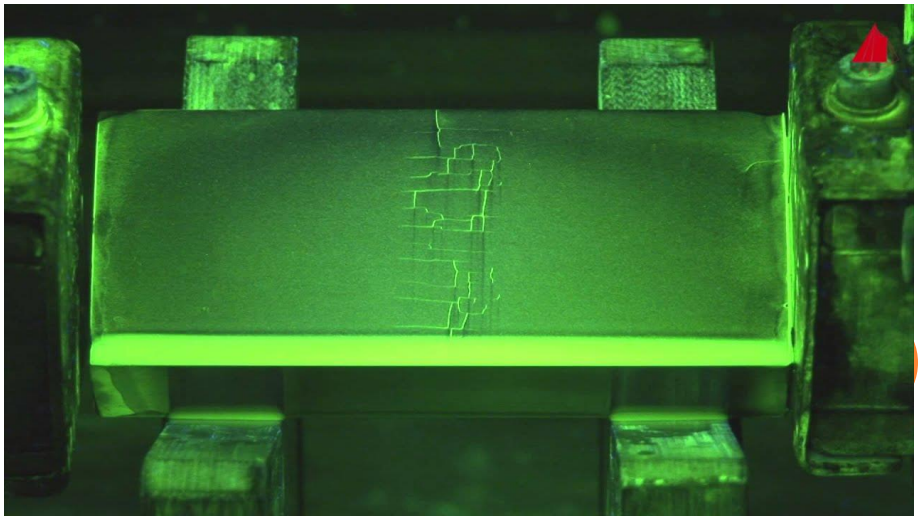
Cleaning

- Cleaning refers to all operations necessary to the **removal of sand, scale, and excess metal** from the casting.
- **Burned-on sand and scale are removed** to improved the surface appearance of the casting. Excess metal, in the **form of fins, wires, parting line fins, and gates**, is removed.
- Inspection of the casting for defects and general quality is performed.





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Moulding

- Moulding is the **process of making a mould cavity** by packing prepared moulding sand around the pattern and **removing the pattern** from the mould to form the mould cavity.

Types

- Green sand moulding
- Dry sand moulding
- Loam moulding

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Moulding Sand

- Special type of sand used for making mould is called moulding sand

Constituents of moulding sand

- Sand
- Binder
- Additive

Types of Moulding sand

- Green sand
- Dry sand
- Facing sand
- Loam sand
- Backing sand
- Parting sand

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Green sand

- 8% water, 16 to 30% clay, soft, light and porous ,High damping capacity

Dry sand

- Dry in nature, High strength and rigidity

Facing sand

- Mixture of silica and dry sand
- Normally used to cover the surface of the pattern (fine finish)

Loam sand

- Fine silica, fine refractories, clay, graphite, fiber and water
- It becomes very hard when it is dried

Backing sand

- Old sand, can be used repeatedly

Parting sand

- Mixture Silica and brick powder, used to avoid the sticking of patterns while removing (split pattern)

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Binder

- Organic binder – cereal, resins, drying oils, molasses etc.
- Inorganic binder – clay (fire clay, bentonite, kaolinite)

Additives

- Sea coal, sawdust, pitch, cereals, silica flour, fuel oil

Properties of moulding sand

- Porosity or permeability
- Plasticity or flowability
- Adhesiveness
- Strength or cohesiveness
- Refractoriness
- collapsibility

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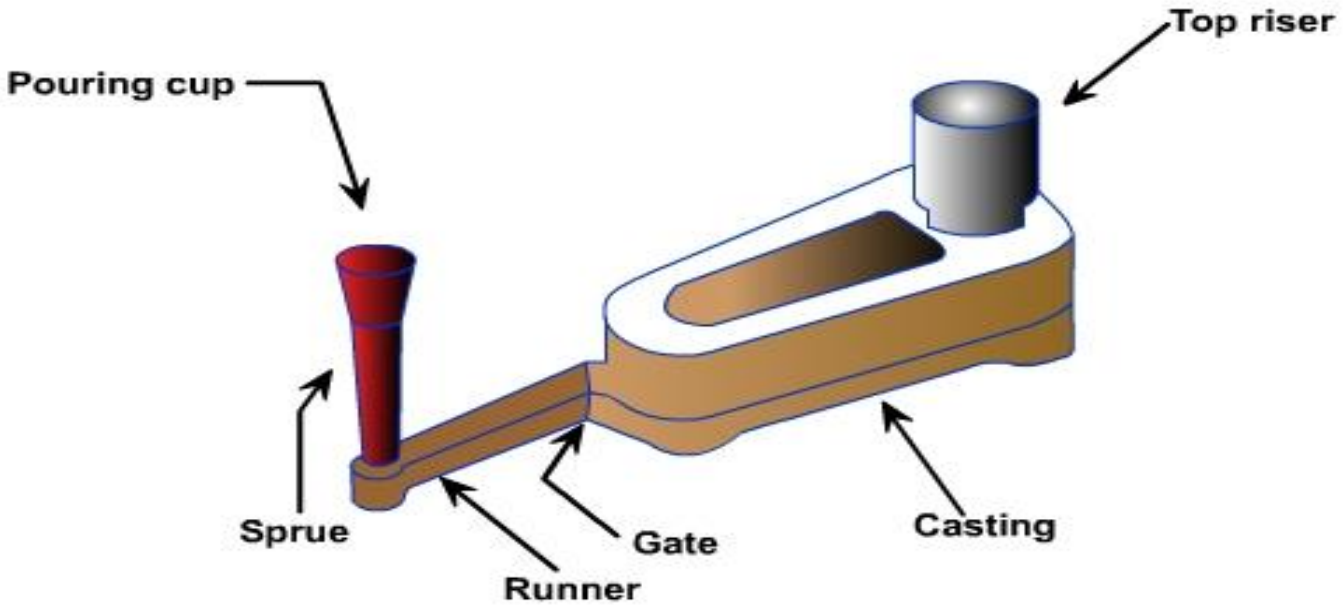
Gating and Risering



A typical pattern attached with gating and Risering system

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Gating and Risering

- GATE -A channel through which the molten metal enters the mold cavity.

The goals for the gating system are;

- To **minimize turbulence** to avoid trapping gases and breaking up the sand mold.
- To get enough **metal into the mold cavity** before the metal starts to solidify.
- To **avoid shrinkage**

Gating and Risering

- Riser -A column of molten metal placed in the mold **to feed the castings as it shrinks** and solidifies. Also known as "feed head".

The Purpose of Riser system is;

- To provide that extra molten metal. Basically **a riser is a vertical portion of the gating** system, similar to a **straight sprue**, that stores the **molten metal until it is needed** by the casting.
- This means the metal in the **riser must stay liquid longer** than the metal in the part being cast.
- To **avoid shrinkage**

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Pattern making

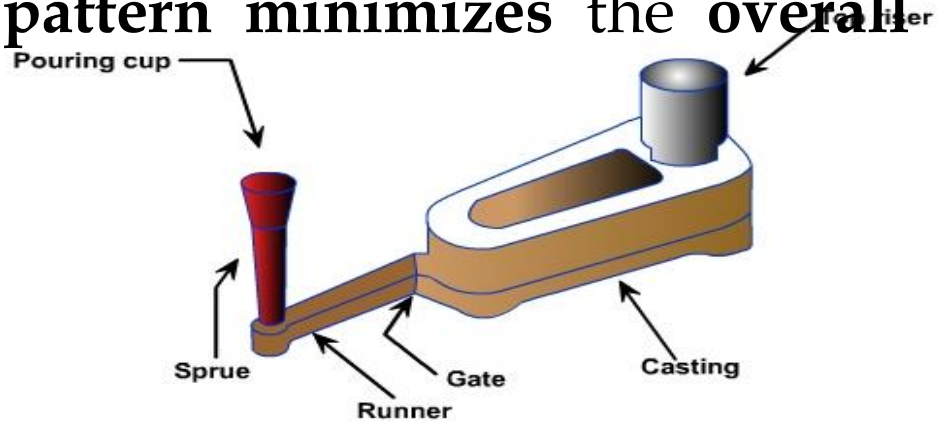
- A replica of the object about to be cast.
- The pattern is a **physical model of the casting** used to make the mold.
- Pattern making is one of **the first and most important** steps in the casting process.
- Usually made out of **wood, metal or model board,** patterns are used to create cavities in moulds.
- When the pattern is withdrawn, its imprint provides the mold cavity, which **is ultimately filled with metal** to become the casting. If the **casting is to be hollow**, as in the case of pipe fittings, additional patterns, **referred to as cores**, are used to form these cavities.

Factors affect the choice of a pattern:

- Number of Castings to be produced.
- Size and complexity of the shape and size of casting
- Type of molding and castings method to be used.
- Machining operation
- Characteristics of castings

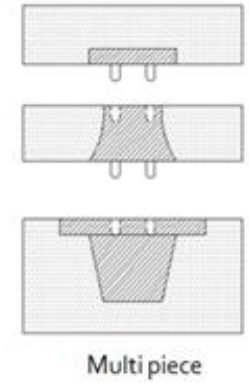
Functions of the Pattern

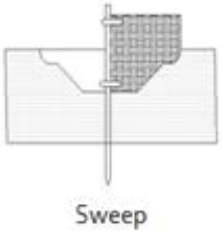
- A **pattern prepares a mold cavity** for the purpose of making a casting.
- A pattern may contain **projections known as core prints** if the casting requires a core and need to be made hollow.
- **Runner, gates, and risers** used for feeding molten metal in the mold cavity may **form a part of the pattern**.
- Properly made **patterns have smooth surface finish** and **reduce casting defects**.
- A properly constructed **pattern minimizes** the **overall cost of the castings**.

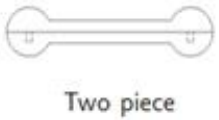


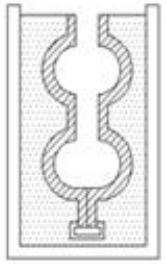
Pattern Types

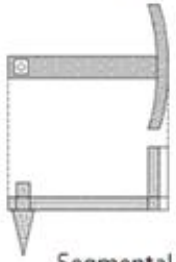
- Solid or single piece pattern
- Split pattern
- Loose piece pattern
- Match plate pattern
- Sweep pattern
- Skeleton pattern
- Cope & Drag pattern
- Shell pattern

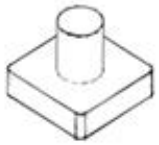


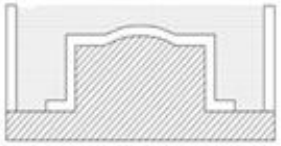


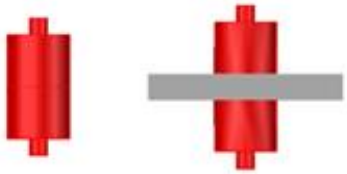


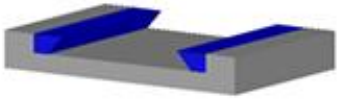


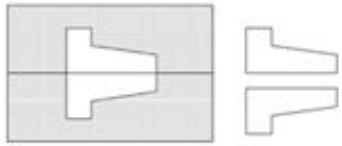




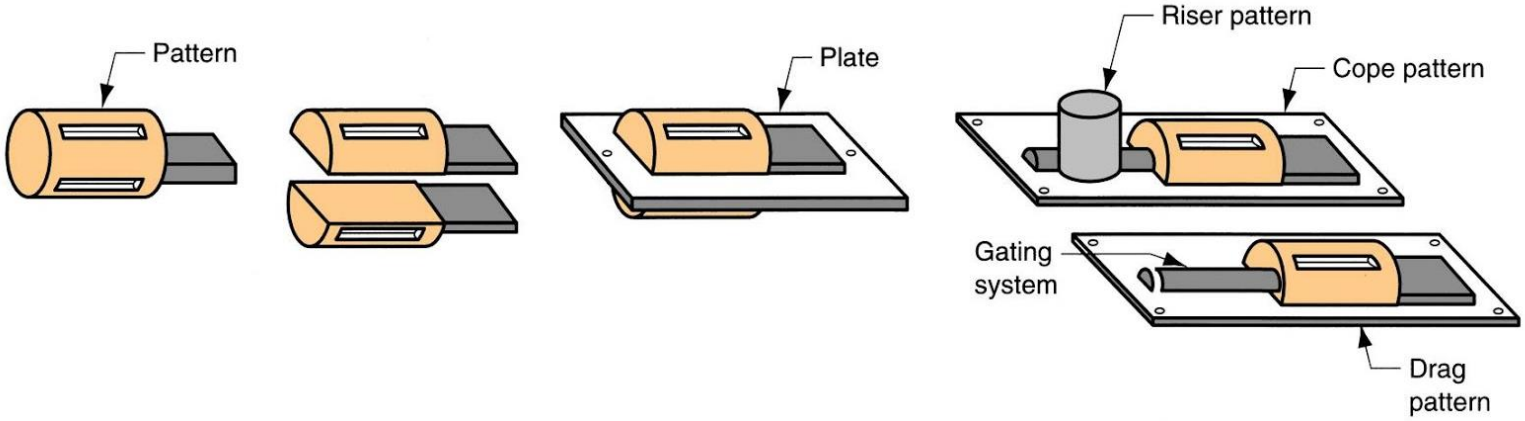








Types of Pattern in Casting



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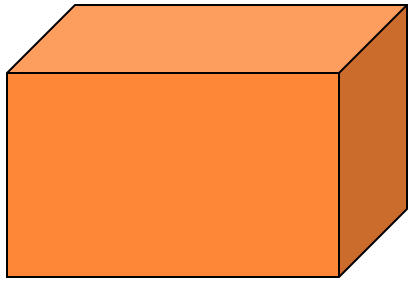
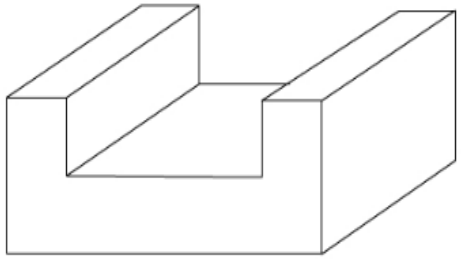
Solid or single piece pattern

- These types of patterns are made of **single solid piece without joints**
- It is made exactly into the **desire casting shape** to be produced with some allowance
- **Removal of pattern** from the sand is **easy**





single piece patterns

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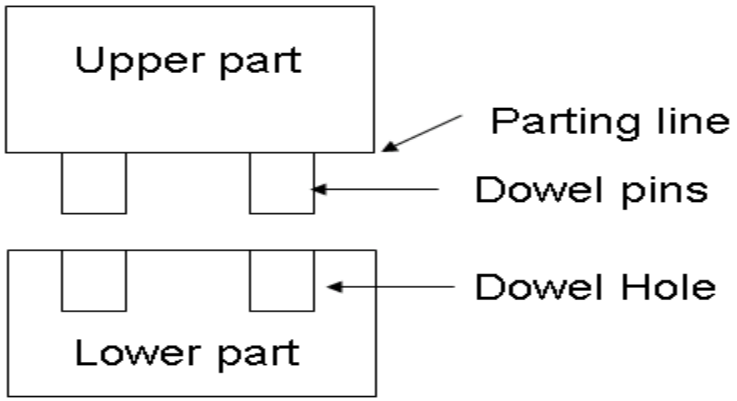
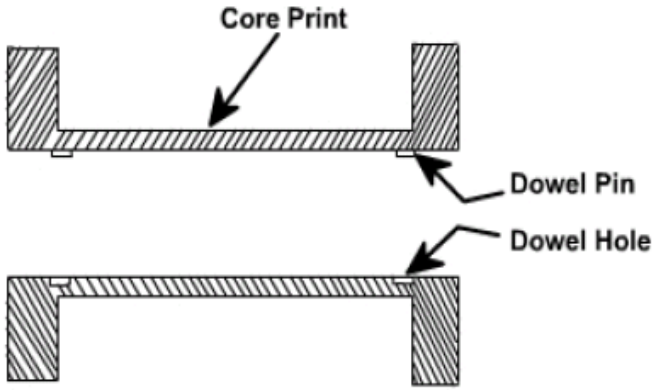
Split pattern

- These types of patterns are made up of two parts. One part is used to produce the **lower half of the mould**, where us the other part is used to produce the **upper half of the mould.**
- The two parts are assembled together in **correct position by pins called dowel pins**. The line separating two parts is called parting line
- Split or two piece pattern is most widely used type of pattern for **intricate castings**





Split patterns

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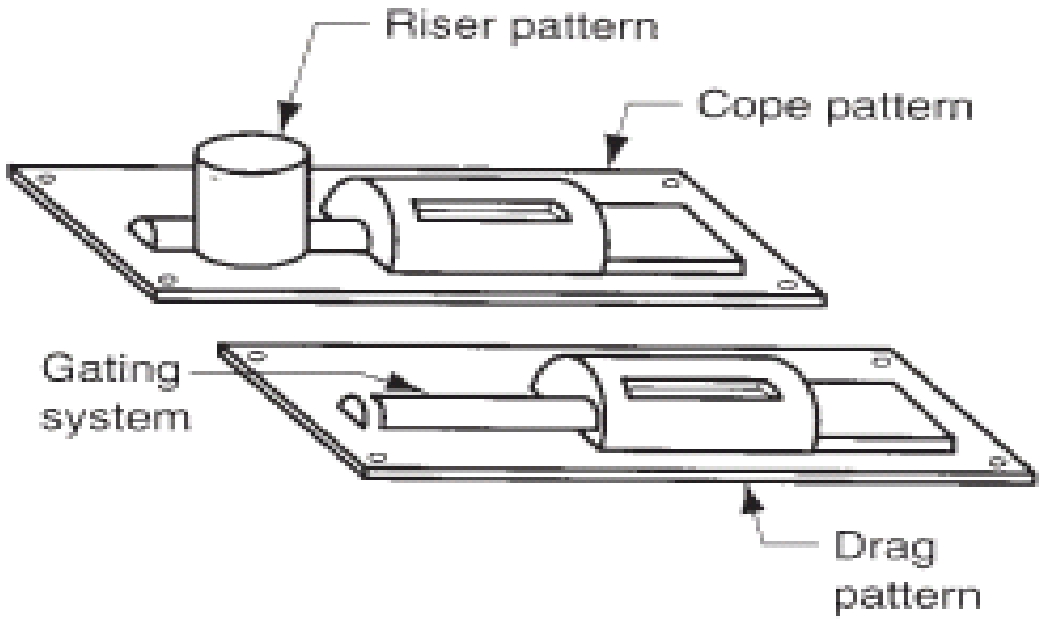
Cope and drag pattern

- A split pattern which has **cope, riser and gating** arrangement.
- Mainly used for **producing complex shapes**



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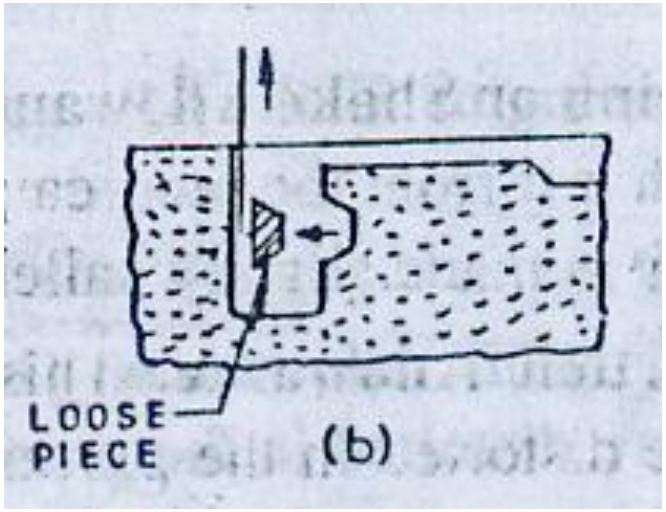
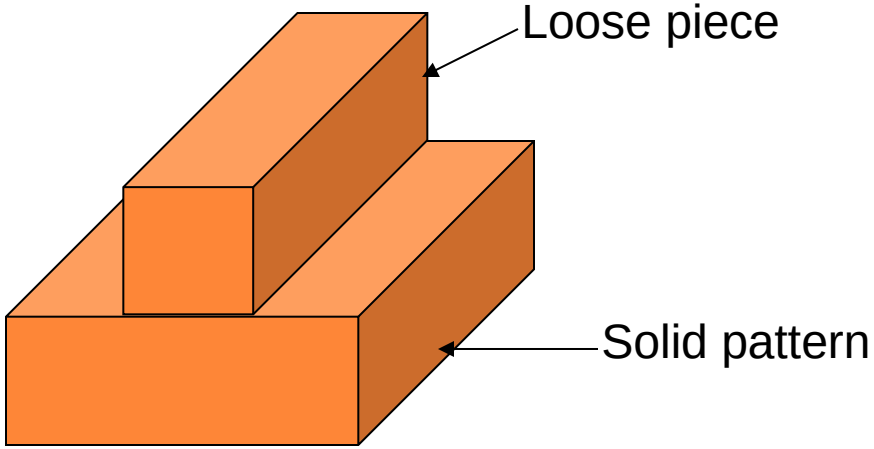
Loose piece pattern

- A pattern which has **loose pieces above or below the solid pattern**
- **Loose patterns are attached** to the main body of the pattern **by pins**





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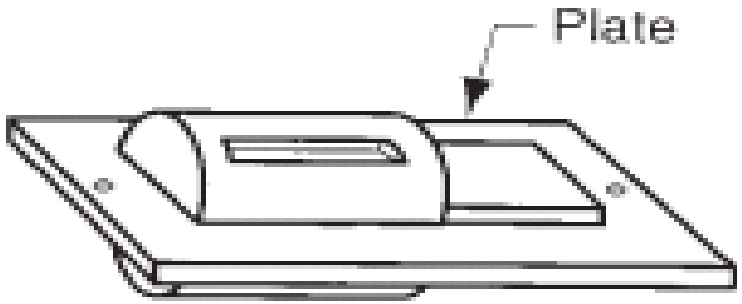
Match plate pattern

- A pattern is made into **two halves mounted on both sides** of the plate called match plate (Wood or Aluminium)
- Mainly used for machine components moulding.



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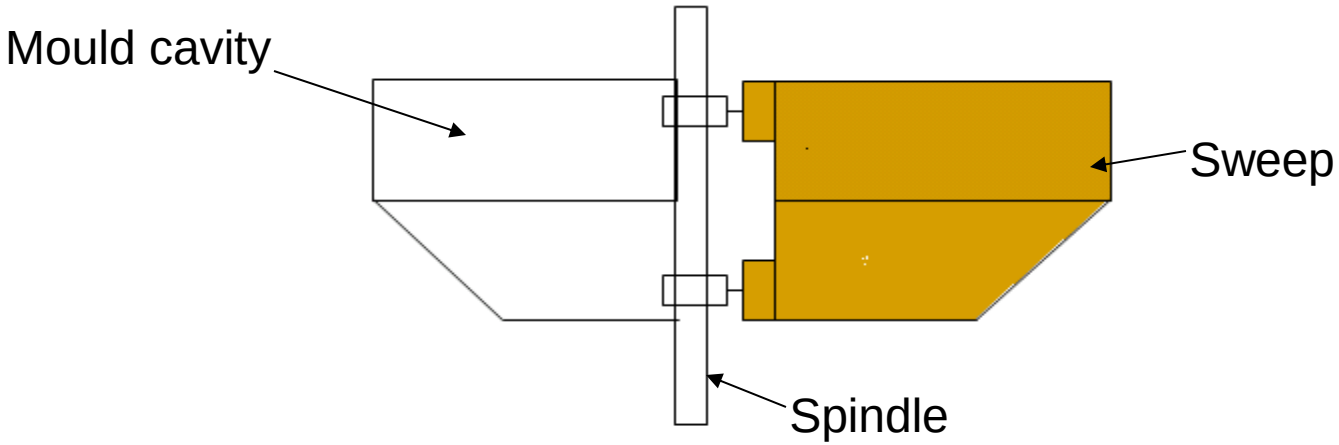
Sweep pattern

- Sweep is a section, made of wood or metal to the required cross section that is **rotated about one edge to shape mould cavities** with rotational symmetry.
- Sweep patterns are mainly used to generate surface of revolution like **cylinder, cone, sphere** in large castings



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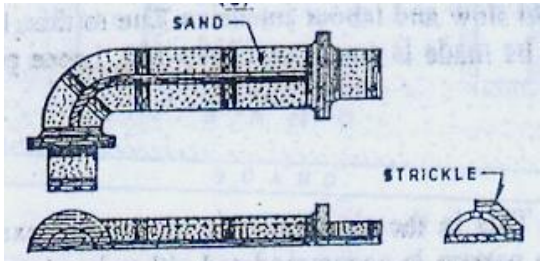
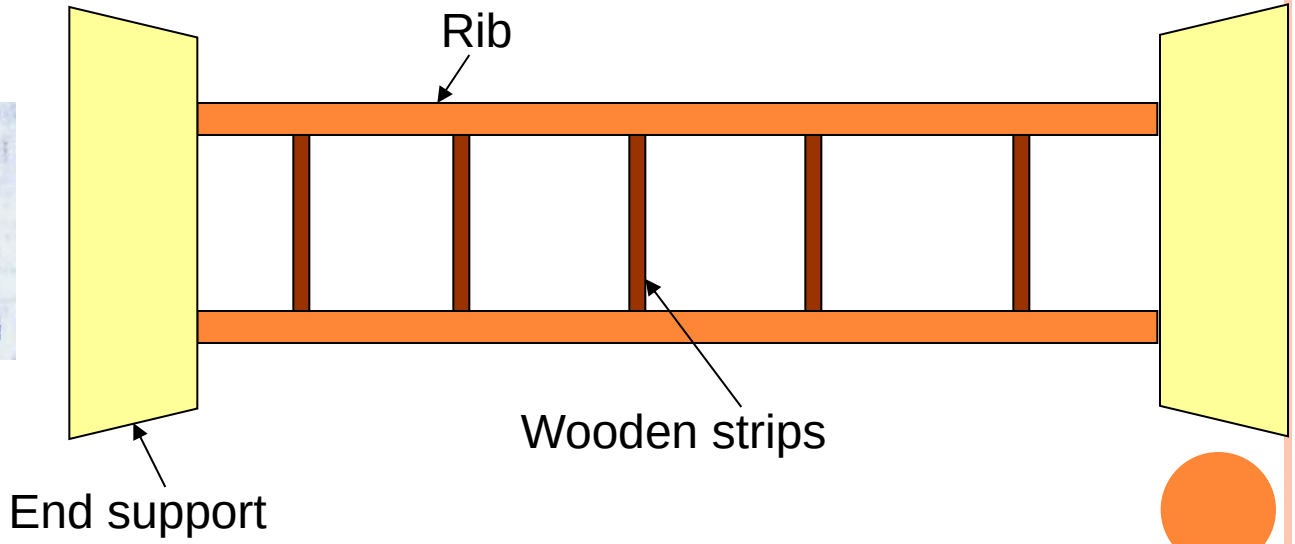
Skeleton pattern

- A skeleton pattern in which **large no of portioning** is made using wooden strips.
- Mainly used to **generate large size castings** having simple shapes





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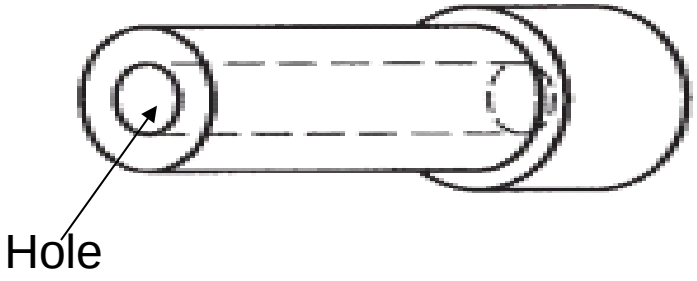
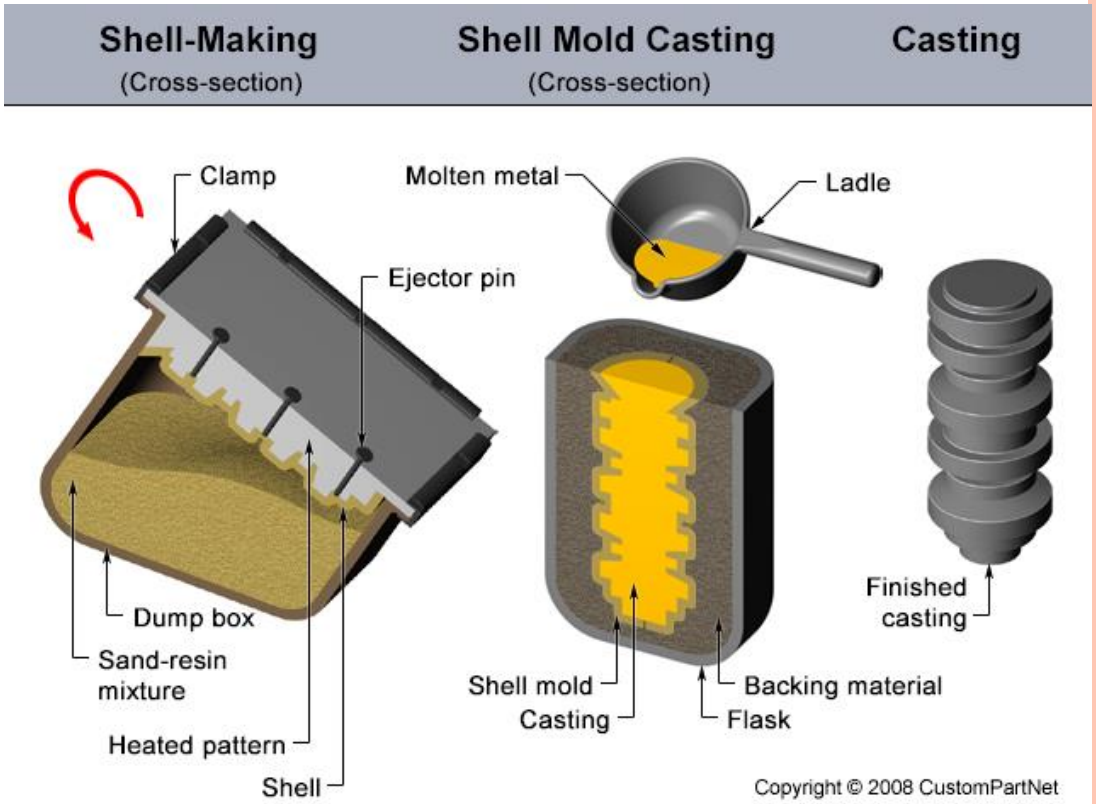
Shell pattern

- A pattern which has **Hollow hole in it**, only the outer shape is used for making the mould.
- The core is prepared as inner surface of the pattern itself





Manufacturing Technology

Pattern Material

- Patterns may be constructed from the following materials.
  - Each material has its own **advantages, limitations, and field of application**.
- Some materials used for making patterns are: wood, metals and alloys, plaster of Paris, plastic and rubbers, wax, and resins.

Manufacturing Technology

To be suitable for use, the pattern material should be:

- Easily **worked, shaped** and **joined**
- Light in weight
- Strong, hard and durable
- Resistant to **wear and abrasion**
- Resistant to **corrosion**, and to chemical reactions
- **Dimensionally stable** and unaffected by variations in **temperature and humidity**
- Available at **low cost**

Manufacturing Technology

Pattern Allowances

- Shrinkage allowance
- Machining or finishing allowance
- Draft or Taper allowance
- Distortion or Camber allowance
- Rapping or shake allowance

Manufacturing Technology

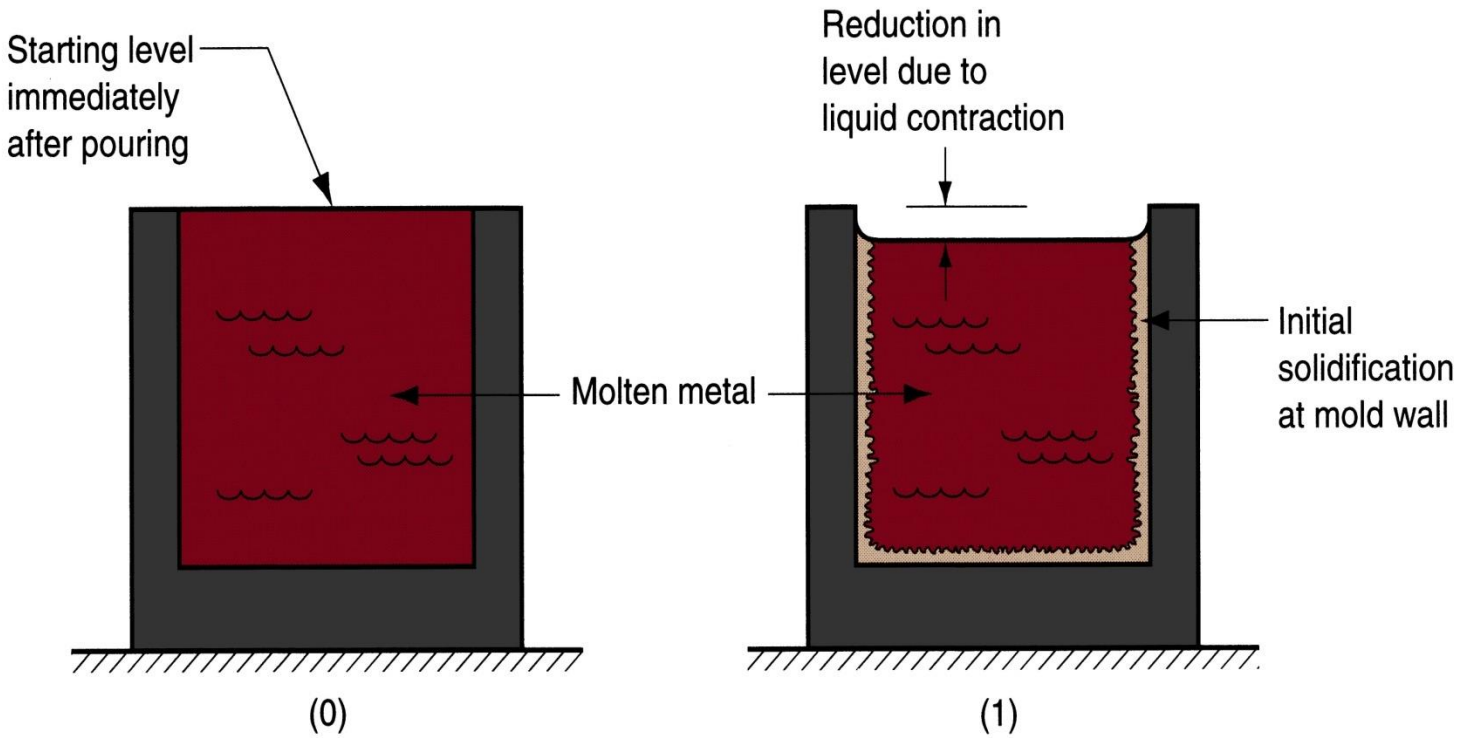
Shrinkage Allowance

- Almost all cast metals **shrink or contract volumetrically** on cooling. The metal shrinkage is of two types:
- **Liquid Shrinkage**:
  - It refers to the **reduction in volume** when the metal changes from **liquid state to solid state** at the solidus temperature.
  - To account for this shrinkage; **riser, which feed the liquid metal to the casting**, are **provided in the mold**.
- **Solid Shrinkage:**
  - It refers to the **reduction in volume caused when metal loses temperature in solid state**. To account for this, shrinkage **allowance is provided on the patterns**.

Manufacturing Technology

Shrinkage Allowance

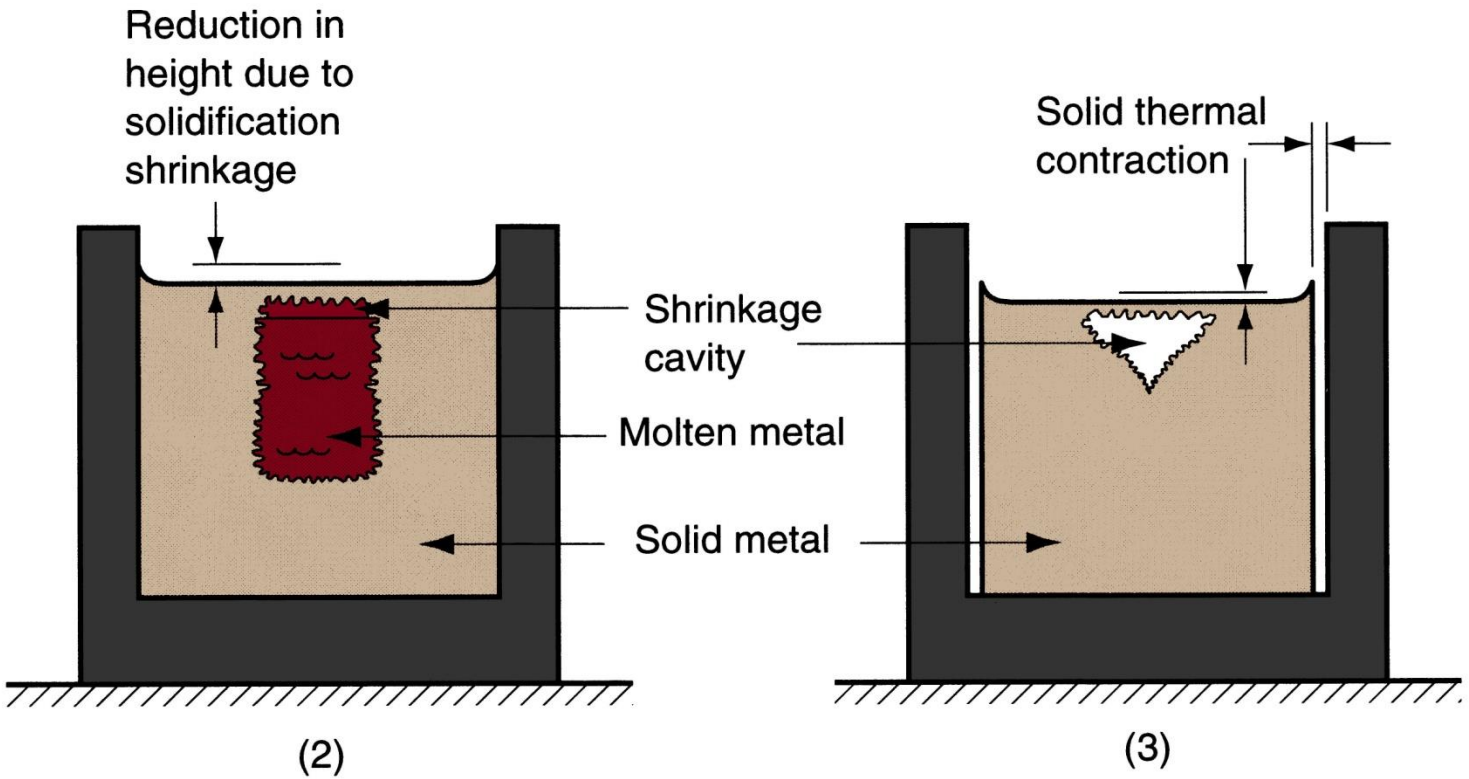
- **Liquid Shrinkage**:



Manufacturing Technology

Shrinkage Allowance

- **Solid Shrinkage**:



Manufacturing Technology

Machining or Finish Allowance

- The finish and accuracy achieved in sand casting are generally poor.
- when the casting is functionally required to be of **good surface finish or dimensionally accurate**, it is generally achieved by **subsequent machining**.
- Machining or finish allowances are therefore added in the pattern dimension.
- The amount of machining allowance is affected by the method of **molding and casting (Pattern/Product - Design According)**

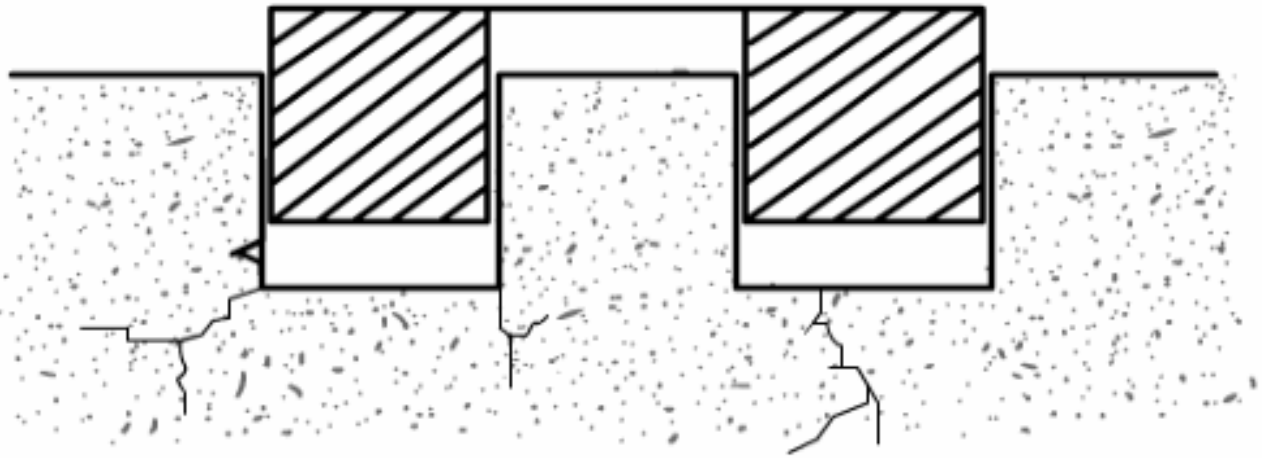
Manufacturing Technology

Draft or Taper Allowance

- Draft indicates the taper in the pattern (on all **vertical surfaces of the pattern)**
- To **remove the pattern from the sand** without **tearing away the sides** of the sand mold and without excessive **rapping** (shaking side to side) by the molder.

Manufacturing Technology

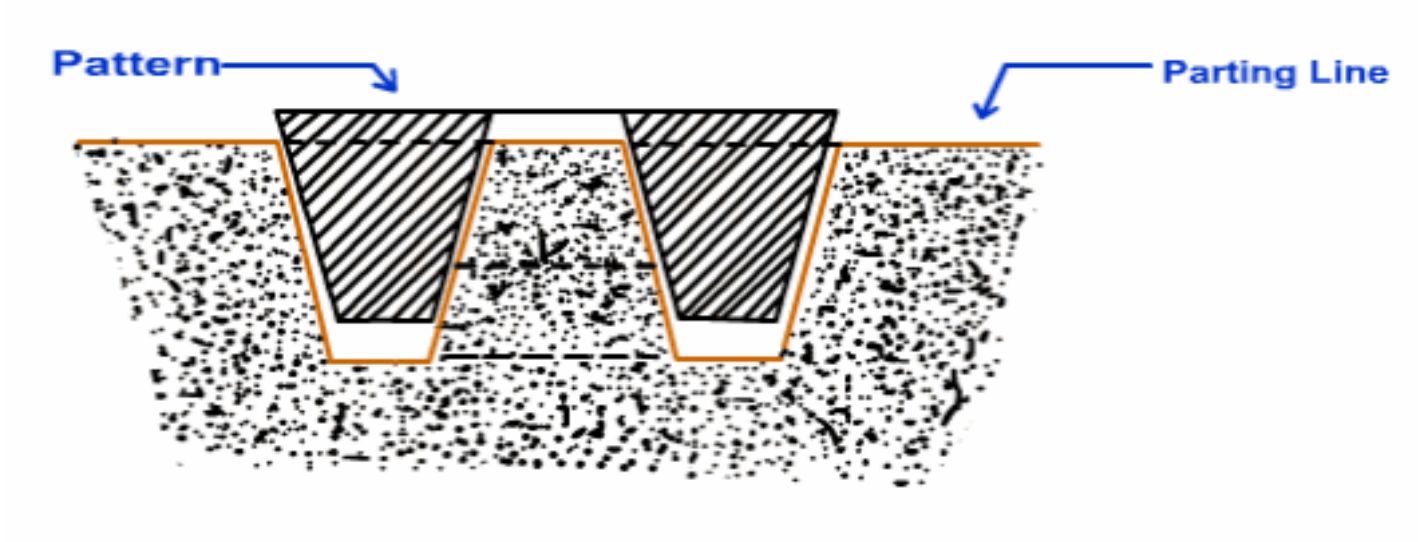
- Figure shows a pattern having no draft allowance being removed from the pattern.
- Till the pattern is completely lifted out, its sides will **remain in contact with the walls** of the mold (tending to break).



Pattern Having No Draft on Vertical Edges

Manufacturing Technology

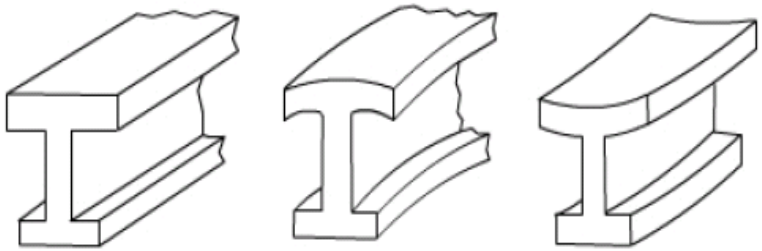
- Figure show a pattern having proper draft allowance. Here, the moment the **pattern lifting commences**, all of its surfaces are well away from the sand surface.
- Thus the **pattern can be removed without damaging** the mold cavity.



Pattern Having Draft on Vertical Edges

Manufacturing Technology

Distortion or Camber Allowance



- Sometimes **castings get distorted**, during solidification, due to their typical shape.
  - If the casting has the form of the letter **(shapes) U, V, T, or L etc**. it will tend to **contract at the closed end causing** the vertical legs to look **slightly inclined**.
- This can be **prevented by making** the legs of the U, V, T, or L shaped pattern **converge slightly (inward)** so that the **casting after distortion** will have its sides vertical

Manufacturing Technology

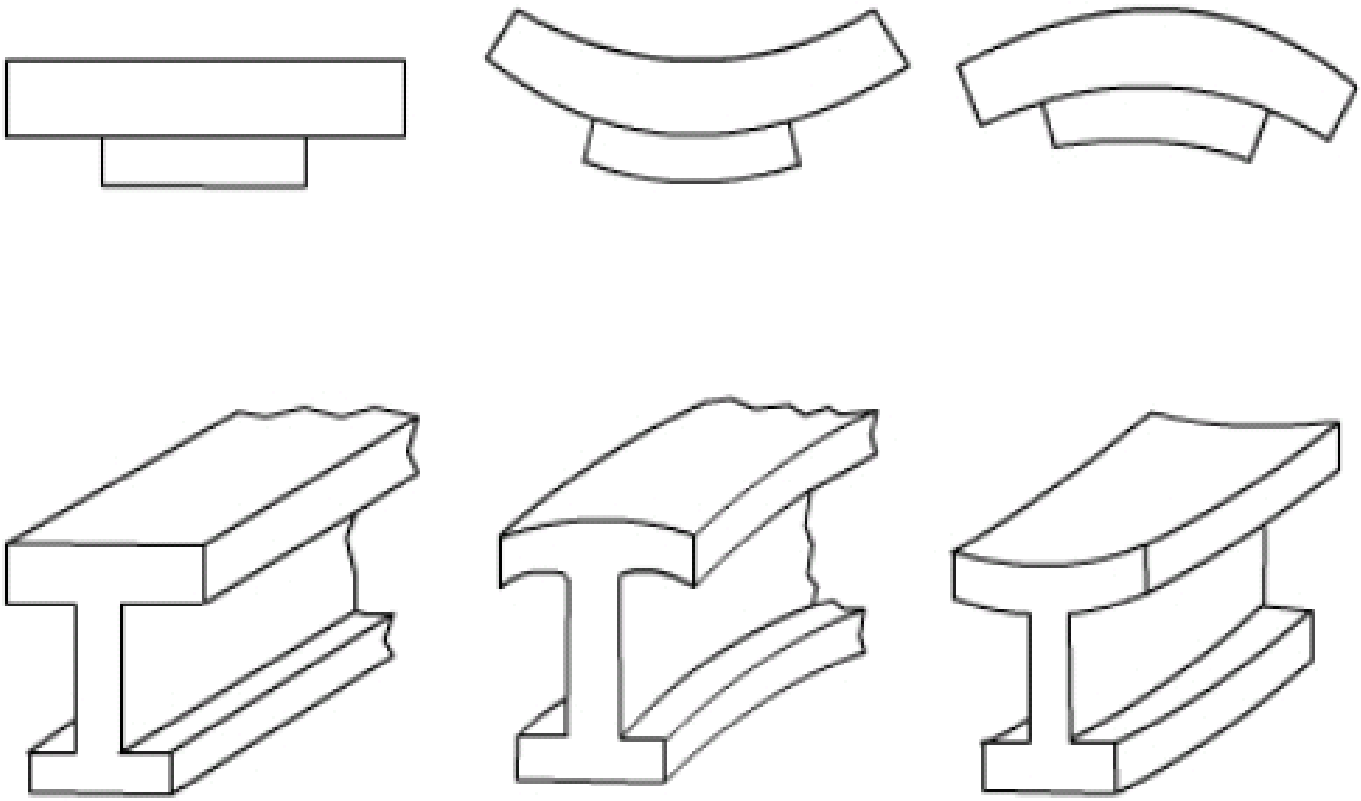
- The distortion in casting may occur due to **internal stresses.**
  - These **internal stresses are caused** on account of **unequal cooling** of different section of the casting and **hindered contraction**.

Measure taken to prevent the distortion in casting include:

- Modification of casting design
- Providing sufficient machining allowance to cover the distortion effect
- Providing suitable allowance on the pattern, called camber or distortion allowance (inverse reflection)

Manufacturing Technology

Distortions in Casting



Manufacturing Technology

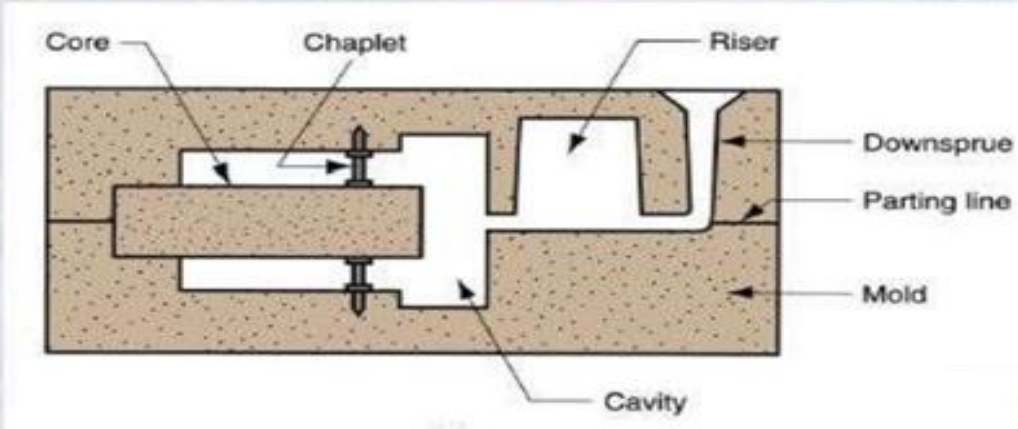
Rapping or shake allowance

- Before the withdrawal from the sand mold, the **pattern is rapped all** around the **vertical faces to enlarge** the mold cavity slightly, which facilitate its removal.
- Since it enlarges the final casting made, it is desirable that the original pattern dimension should be reduced to account for this increase.
- There is no sure way of quantifying this allowance, since it is **highly dependent on the foundry** personnel practice involved.
- It is a negative allowance and is to be applied only to those dimensions that are parallel to the parting plane.

CORES

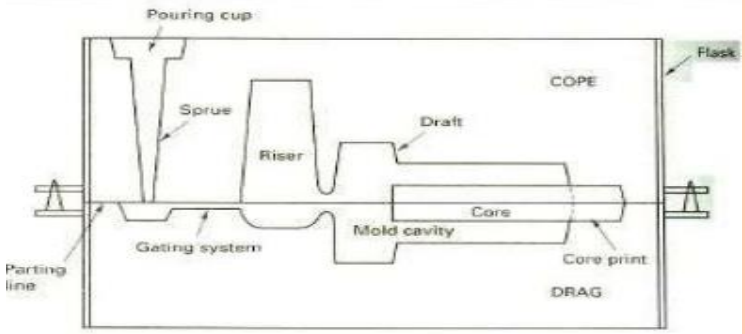
Full-scale model of interior surfaces of part

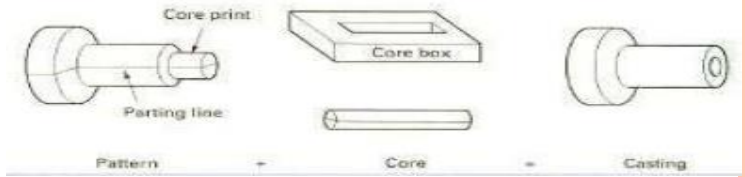
- It is inserted into the mold cavity prior to pouring
- The molten metal flows and solidifies between the mold cavity and the core to form the casting's external and internal surfaces
- May require supports to hold it in position in the mold cavity during pouring, called ***chaplets***



FUNCTIONS (PURPOSES) OF CORES

- The cores are used to **form the internal cavities.**
- Cores are used to **form a part of a green sand mould.**
- Cores are used to **strengthen the moulds.**
- Cores are used as a **part of the gating system.**





Manufacturing Technology

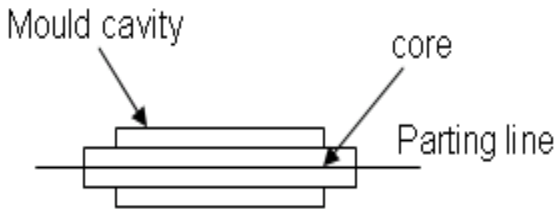
Cores & Core Making

- 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.
- Core Making: The process of **making cores using core sand, binder and additives** with the help of core boxes.

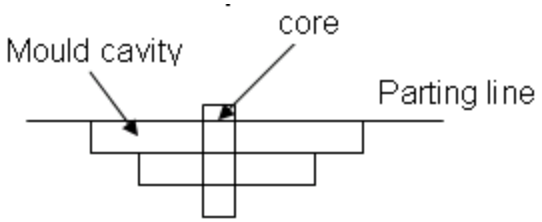
Types of Cores

- Horizontal core – supported Horizontally in the mould
- Vertical core - supported Vertically in the mould
- Balancing core – supported at the ends of the mould
- Hanging core – supported at the top and hung into the mould
- Drop core – supported top or bottom of the parting line

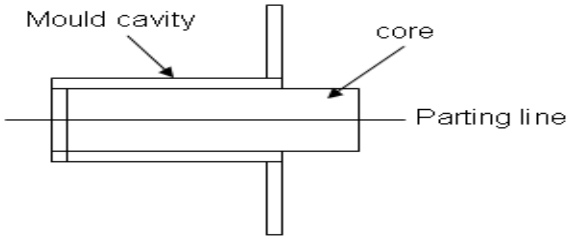
Manufacturing Technology



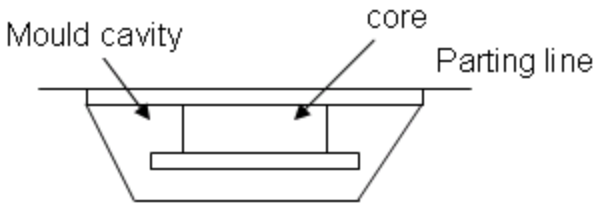
Horizontal core



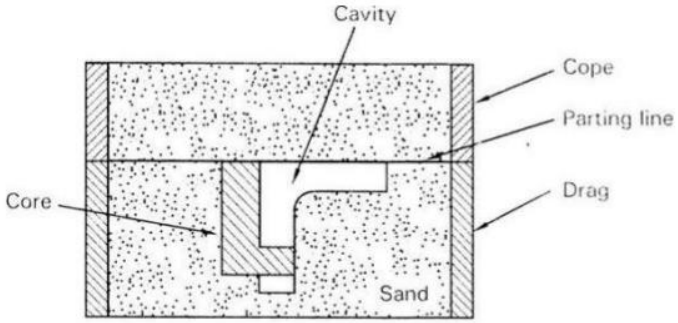
Vertical core



Balancing core



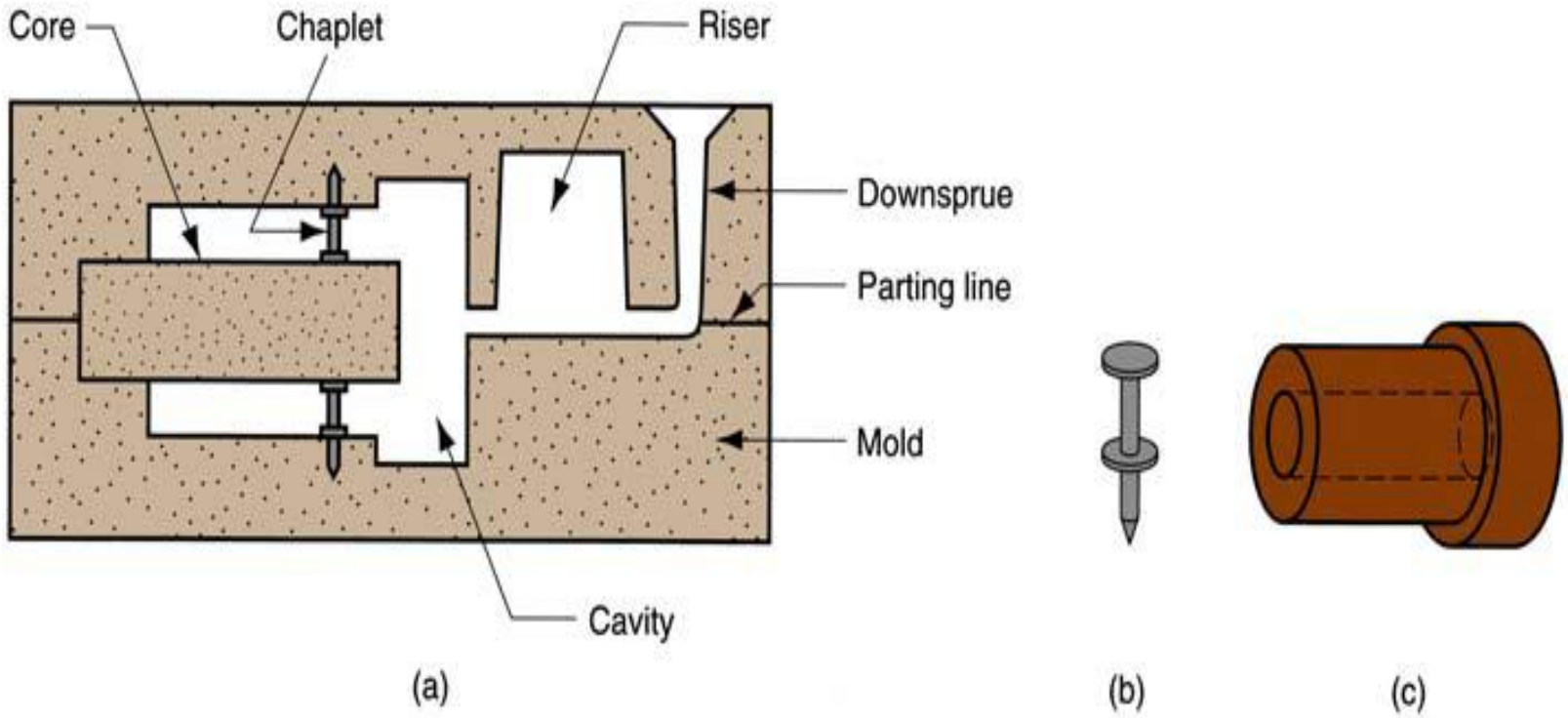
Hanging core



Drop core

Manufacturing Technology

Core and Core Prints



A job & its pattern and the mold cavity with core and core print is shown in Figure

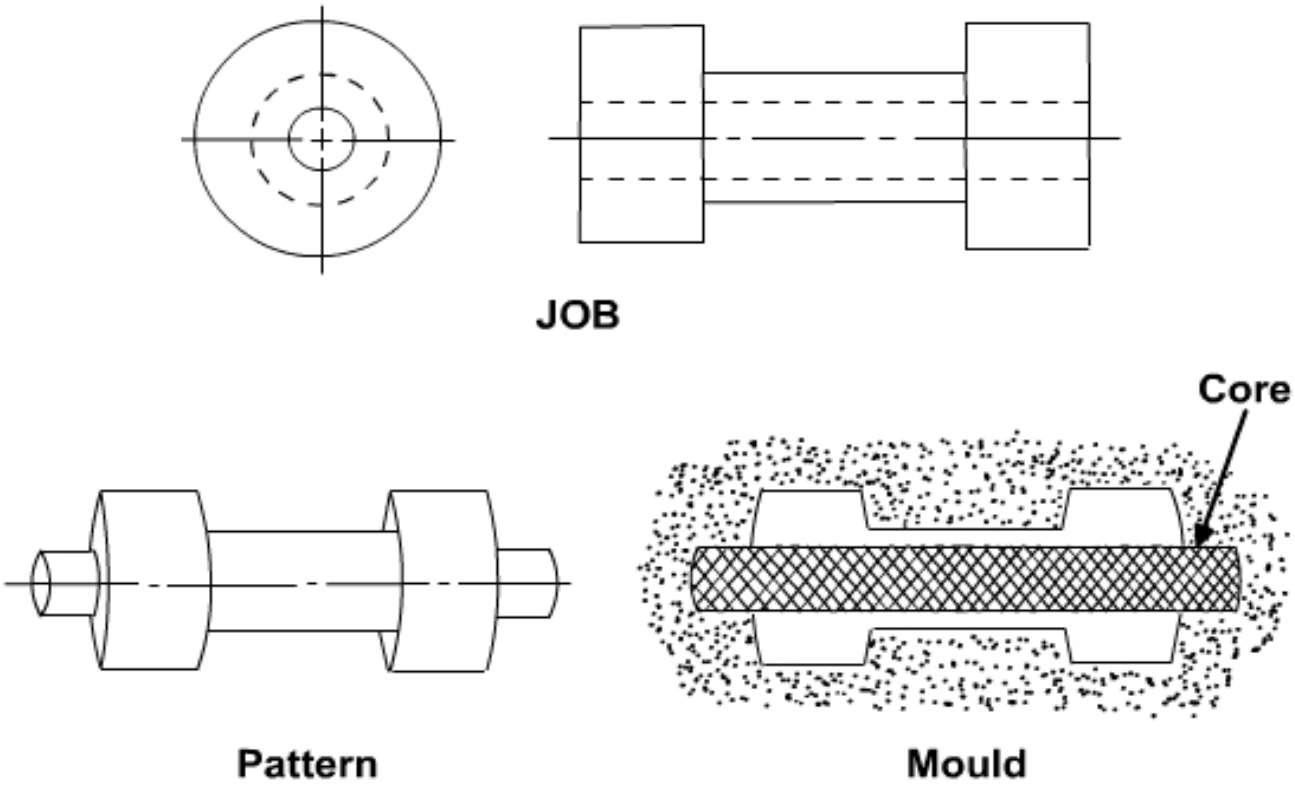
Manufacturing Technology

Core and Core Prints

- Castings are often required to have **holes, recesses,** etc. of various **sizes and shapes**.
- These impressions can be obtained by **using cores**. So where coring is required, **provision should be made to support the core** inside the mold cavity. Core prints are used to serve this purpose.
- The **core print is an added projection** on the pattern and it forms a seat in the mold on which the **sand core rests during pouring** of the mold.
- The **core print** must be of adequate **size and shape** so that it can support the **weight of the core** during the casting operation.
- Depending upon the requirement, a core can be placed horizontal, vertical and can be hanged inside the mold cavity.

Manufacturing Technology

Core and Core Prints



A job & its pattern and the mold cavity with core and core print is shown in Figure

MANUFACTURING TECHNOLOGY

SPECIAL CASTING PROCESS

Manufacturing Technology

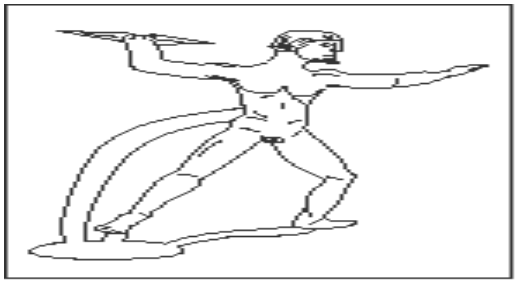
Special Casting Process

- Expandable Mold Casting Processes
  - Shell mold Casting
  - Investment Casting
  - Vacuum mold Casting
  - Expanded polystyrene mold
  - Plaster mold and ceramic mold
- Permanent Mold Casting Processes
  - Die casting
  - Centrifugal casting
  - Basic permanent mold
  - Variations of permanent mold

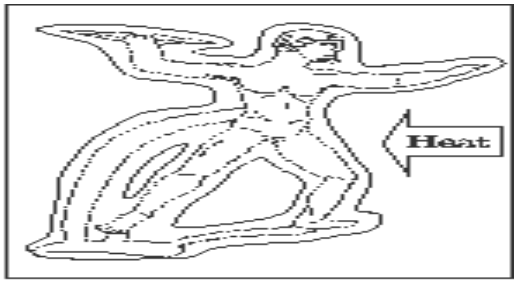
Manufacturing Technology

Special Casting Process

- Expandable Mold Casting
  - In expandable mold casting, the **mold is destroyed to remove** the casting and a **new mold is required** for each new casting.

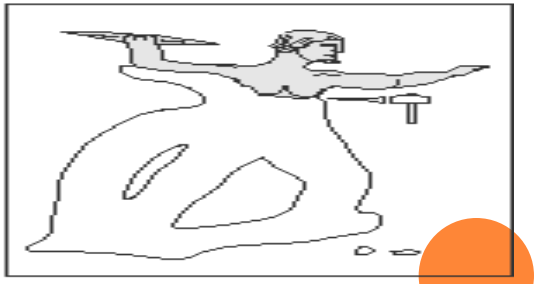


(a)



(b)

(c)



(d)

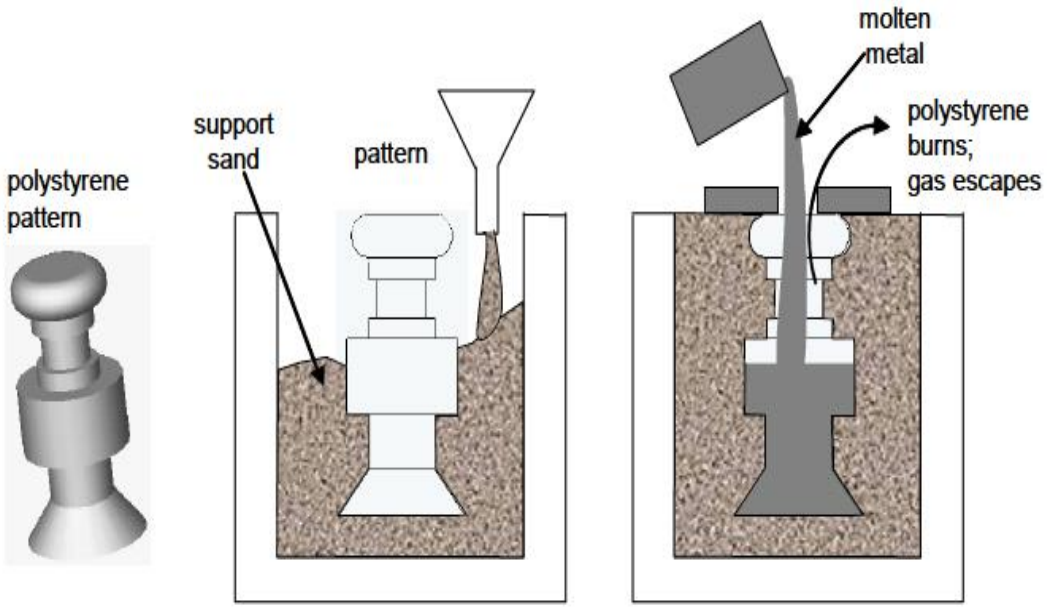
Manufacturing Technology

Expandable Mold Casting Processes

- The pattern used in this process is made from **polystyrene**.
  - This is the **light, white packaging** material which is used to pack electronics inside the boxes. **Polystyrene foam** is 95% air bubbles, and the **material itself evaporates when the liquid metal** is poured on it.
- The **pattern itself is made by molding**
  - **polystyrene beads and pentane** are put inside an **aluminum mold**, and heated; it expands to **fill the mold**, and takes the shape of the cavity.

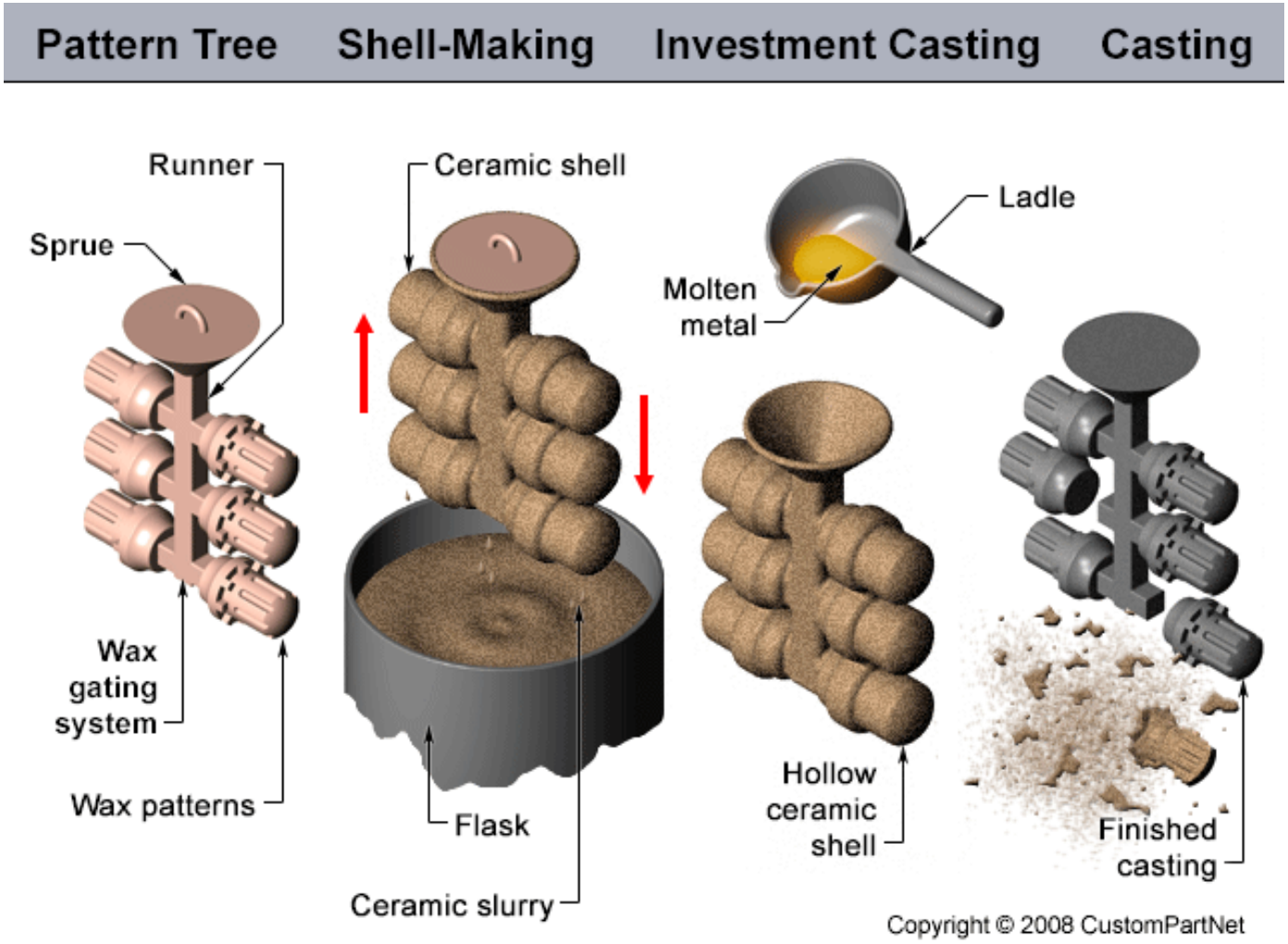
Manufacturing Technology

- The pattern is removed, and used for the casting process, as follows:
  - The **pattern is dipped** in a slurry of water and clay (or other refractory grains); it is dried to get a **hard shell around the pattern**.
  - The **shell-covered pattern** is placed in a container with sand for support, and **liquid metal is poured** from a hole on top.
  - The **foam evaporates** as the metal fills the shell; upon cooling and solidification, the part is removed by breaking the shell.



Manufacturing Technology

Expandable Mold Casting Processes



Manufacturing Technology

Expandable Mold Casting Characteristics

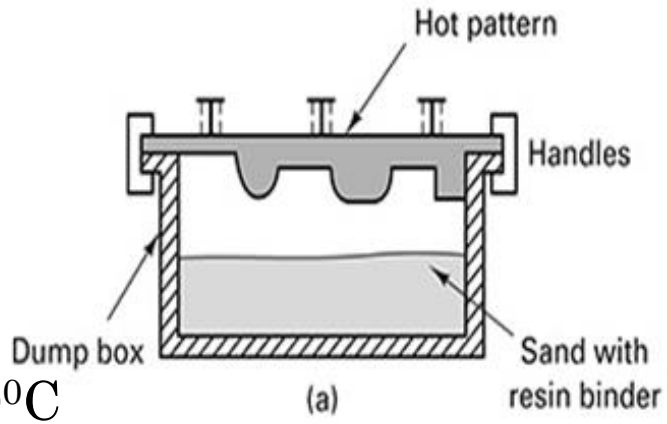
- The process is **very cheap**, and **yields good surface finish** and **complex geometry**.
- There are **no runners, risers, gating** or **parting lines** – thus the design process is simplified.
- The process is used to manufacture **crank-shafts for engines**, aluminum engine blocks, **manifolds** etc.

Manufacturing Technology

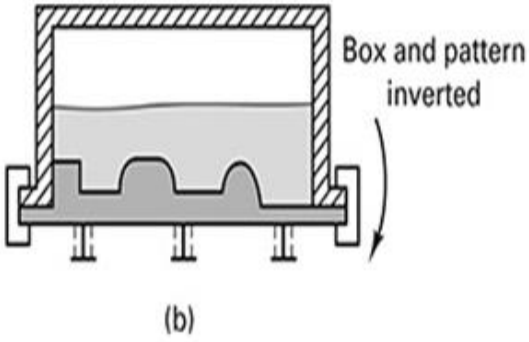
Shell Mold Casting

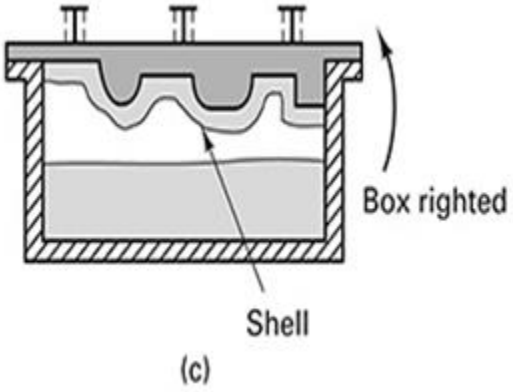
- Shell moulding is a process for producing simple or **complex near net shape** castings, maintaining **tight tolerances** and a **high degree of dimensional stability**.
- The process was developed and patented by **Croning** in **Germany during World War II** and is sometimes referred to as the **Croning shell process**.

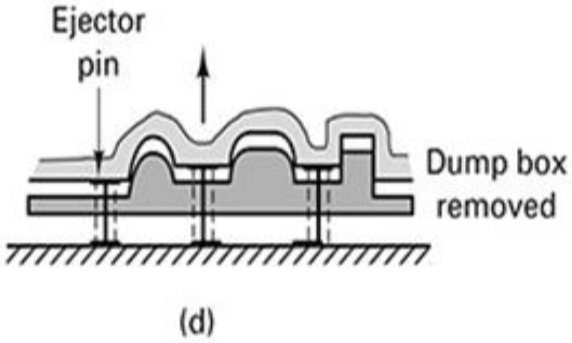
Shell Mold Casting Process



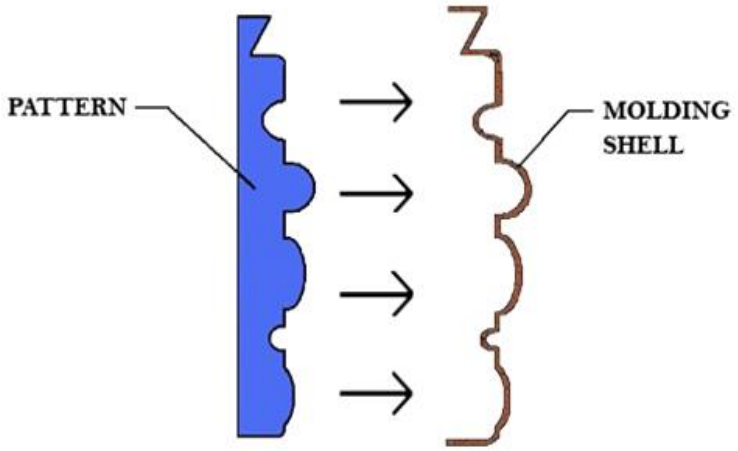
- Initially preparing a **metal-matched plate**
- Mixing resin and sand
- Heating pattern, usually between 250^0C to 260^0C
- Inverting the pattern
  - **The sand is at one end** of a box and the **pattern at the other**, and **the box is inverted** for a time determined by the **desired thickness** of the mill.
- Curing the shell and baking it
- Removing the investment

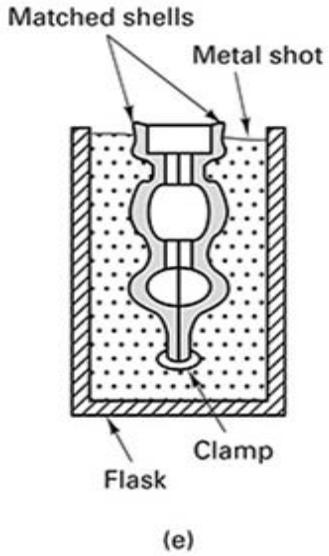




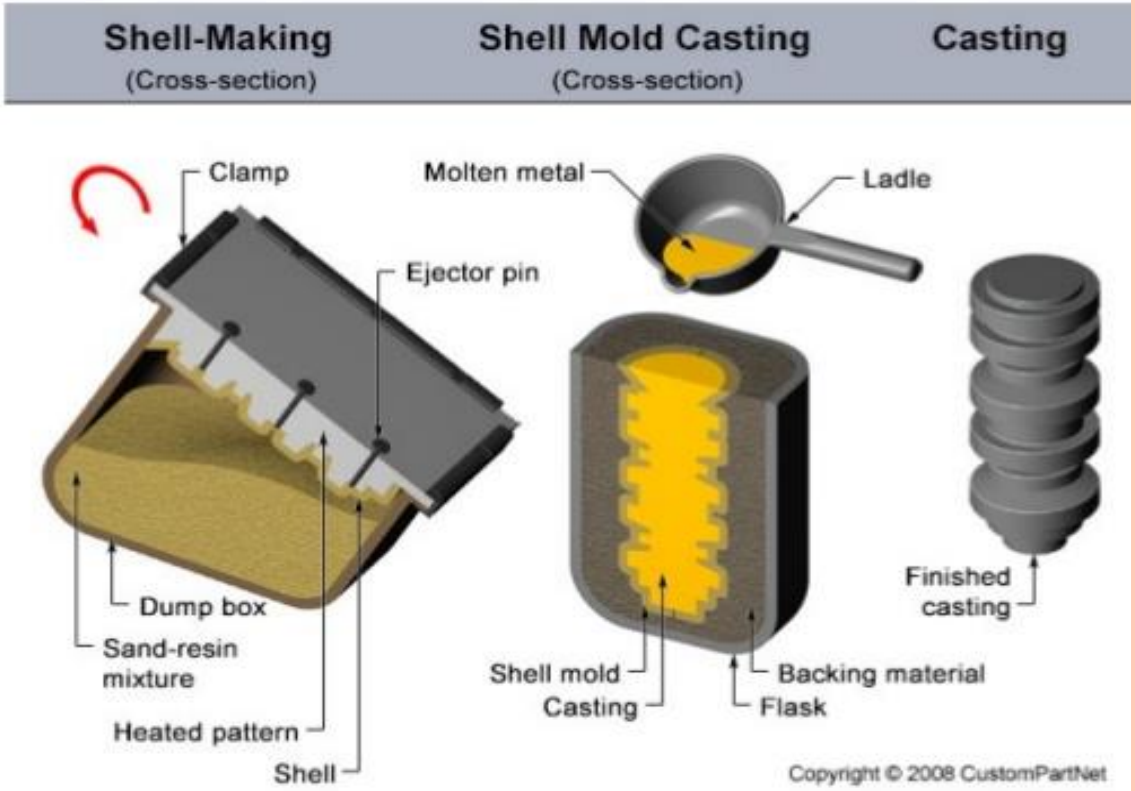


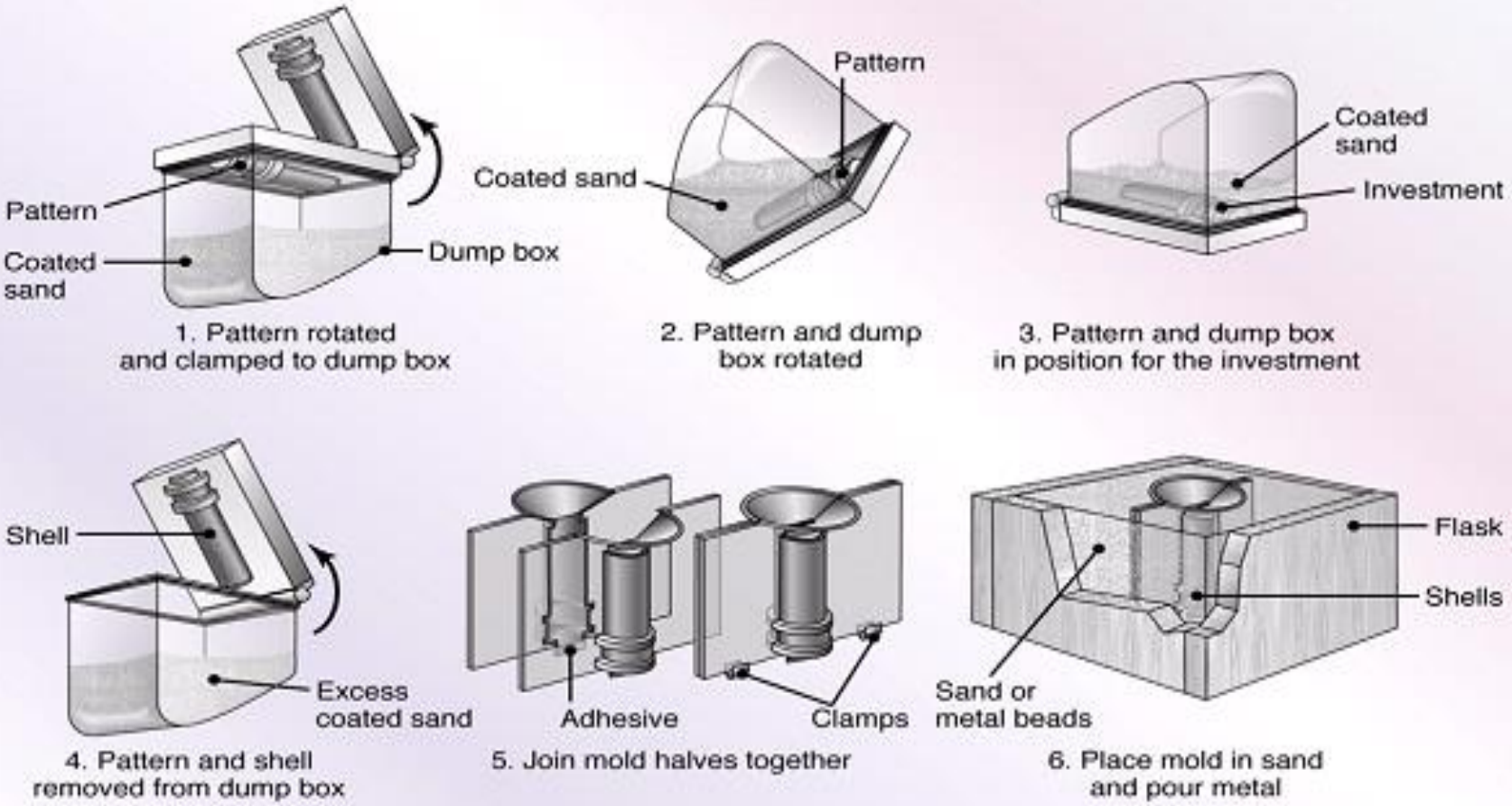
Shell Mold Casting Process





- Inserting cores
- Repeating for the other half
- Assembling the mould
- Pouring the metal
- Removing casting
- Cleaning and Trimming

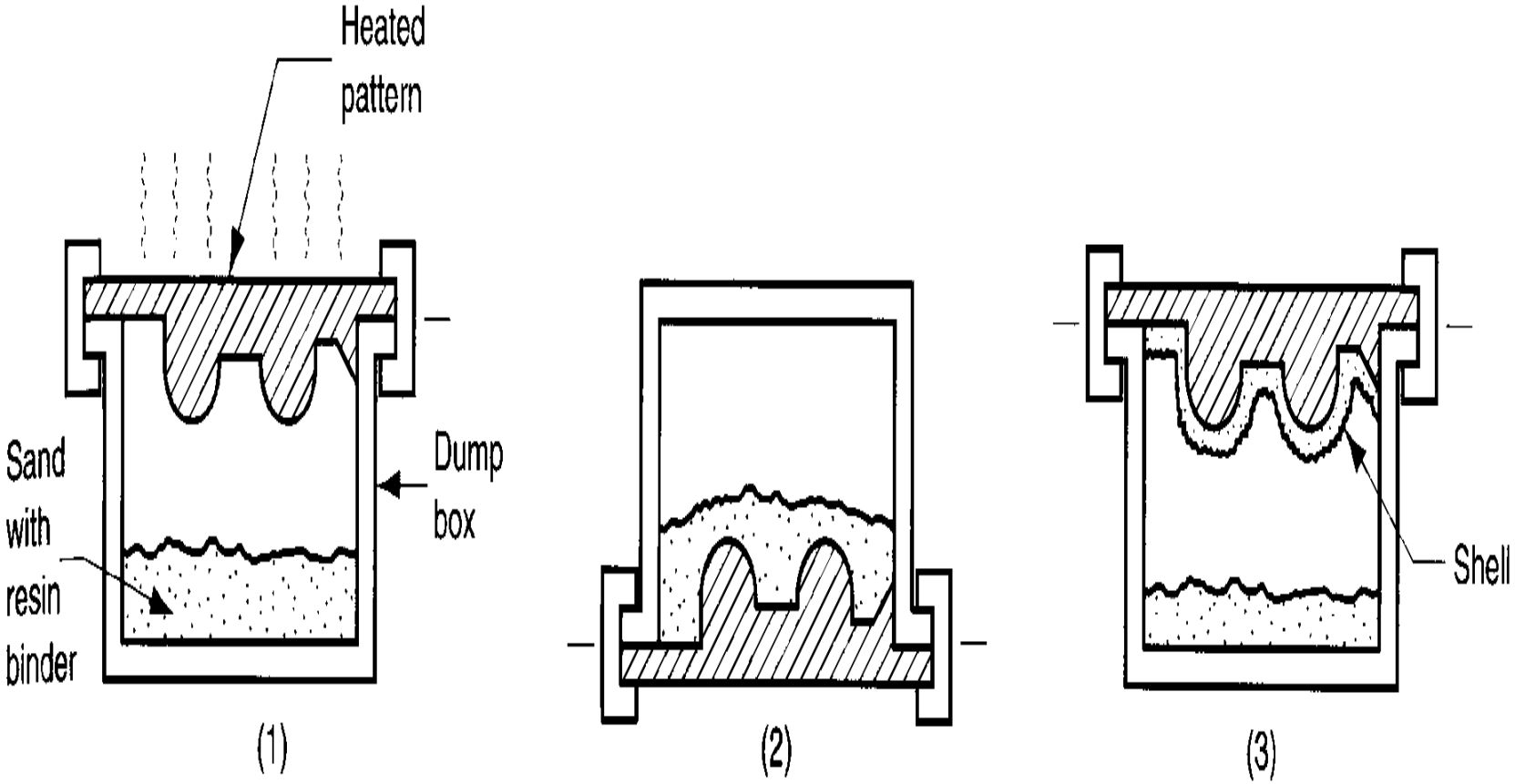




The shell-molding process, also called *dump-box* technique.

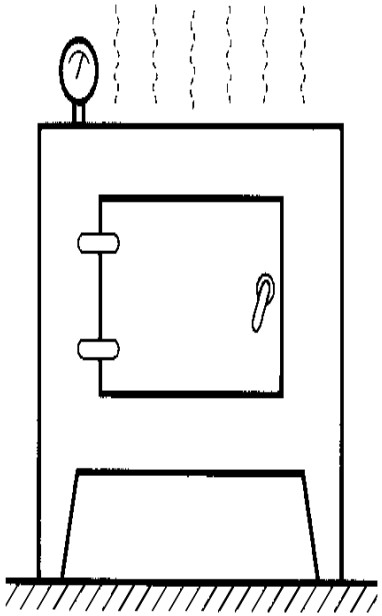
Manufacturing Technology

- Process Steps in Detail



Manufacturing Technology

- Process Steps in Detail



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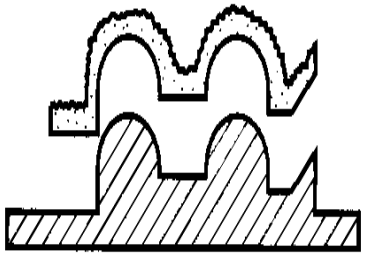
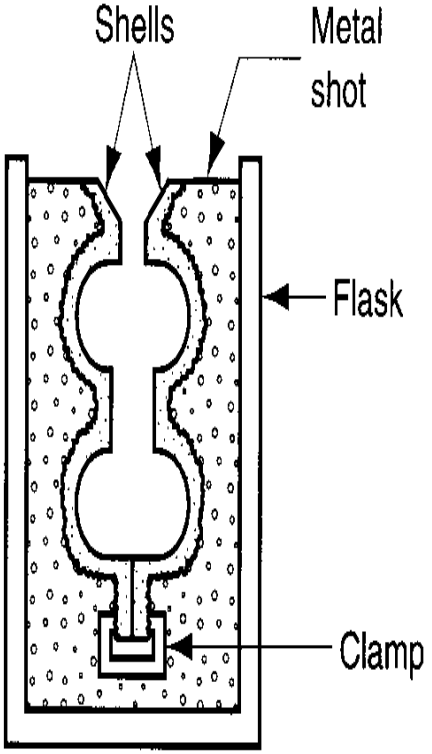


(5)



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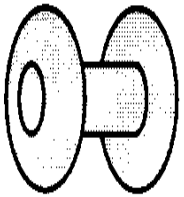


(7)

Manufacturing Technology

1. Heated metal pattern ready for *shell* formation from resin-bonded sand.
2. Box inversion for *shell* formation.
3. Partial cured shell layer hardened; box re-inverted to allow the loose sand particles to be separated.
4. Sand *shell* is heated to complete the curing.
5. Sand *shell* removed from the pattern
6. Two halves of the sand *shell* are assembled and ready for pouring.
7. Finished shell casting with sprue removed.

Manufacturing Technology

Shell Mold Casting Process

- *Advantages*
  - Good surface finish (up to 2.5 mm)
  - Good dimensional accuracy (±0.25 mm)
  - Suitable for mass production
- *Disadvantages*
  - Expensive metal pattern

Manufacturing Technology

- *Area of application*
  - Mass production of **steel casting of less than 10 kg**
  - **Crankshaft** fabrication
  - **Steel casting** parts, fittings
  - Molded tubing fabrication
  - **Hydraulic control housing** fabrication
  - **Automotive castings** (cylinder head and ribbed cylinder fabrication).

Manufacturing Technology

Process Characteristics

- Is superior to other sand casting processes in the accurate **duplication of intricate shapes** and dimensional accuracy
- Process can be **completely mechanized**
- Uses a **thin-walled non-reusable shell** composed of a sand-resin mixture
- Requires a **heated metal pattern** for producing the shell molds
- The process was optimized to get a better shell by varying the temperature of the metal pattern, holding time of sand – resin mixture and final curing time of shell and pattern.

Manufacturing Technology

Investment casting

- Also Named as **lost wax casting**, because of the use of wax patterns which are **coated with a refractory** (i.e. the patterns are invested in alternate layers of slurry and stucco), with the wax patterns subsequently melted out to leave a **hollow shell into which the metal** is cast.
- It is an **extremely slow process** and the production rate is governed by the time to make the mould.

Manufacturing Technology

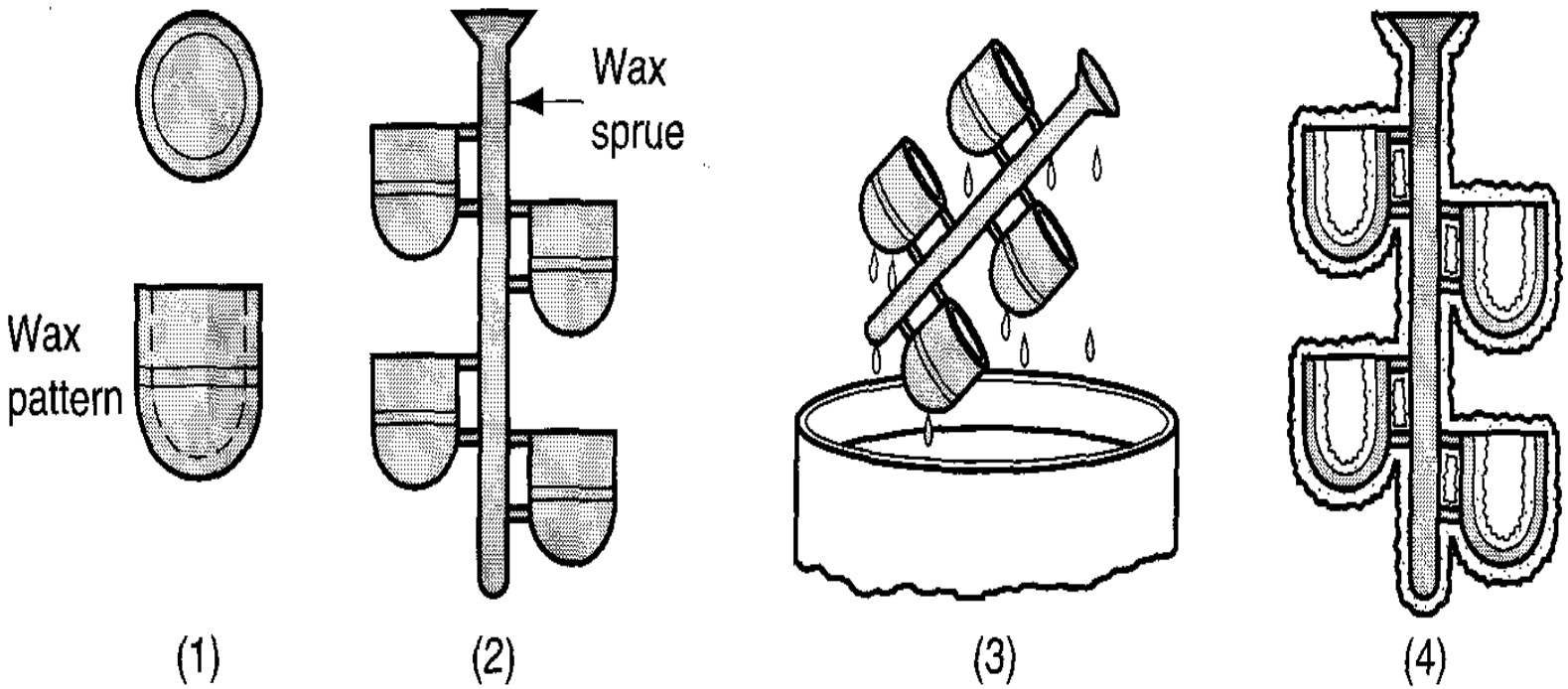
Investment casting Process

- This process uses **wax patterns assembled in tree forms** on a runner. The completed assembly is coated with a **ceramic slurry**, allowed to dry and then heated to melt out the wax leaving a ceramic mould into which the molten alloy is poured.
- Parts made with investment castings **often do not require any further machining**, because of the close tolerances that can be achieved.

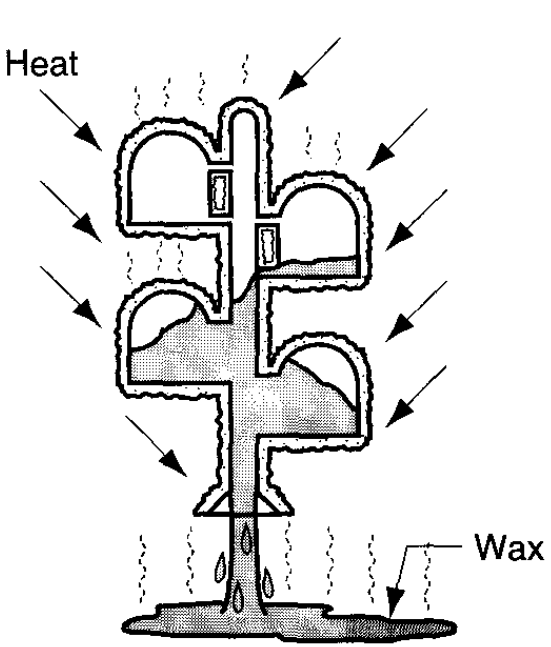
Manufacturing Technology

Processing Steps

- Example 1



Manufacturing Technology



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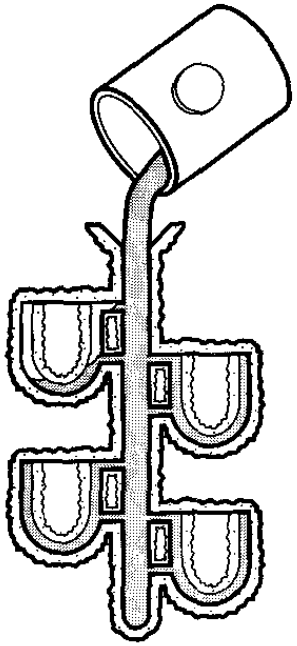

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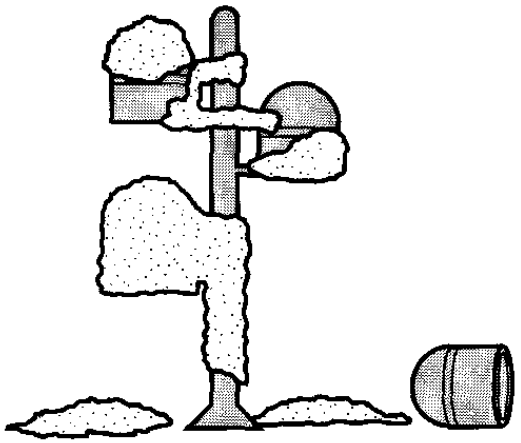


(7)

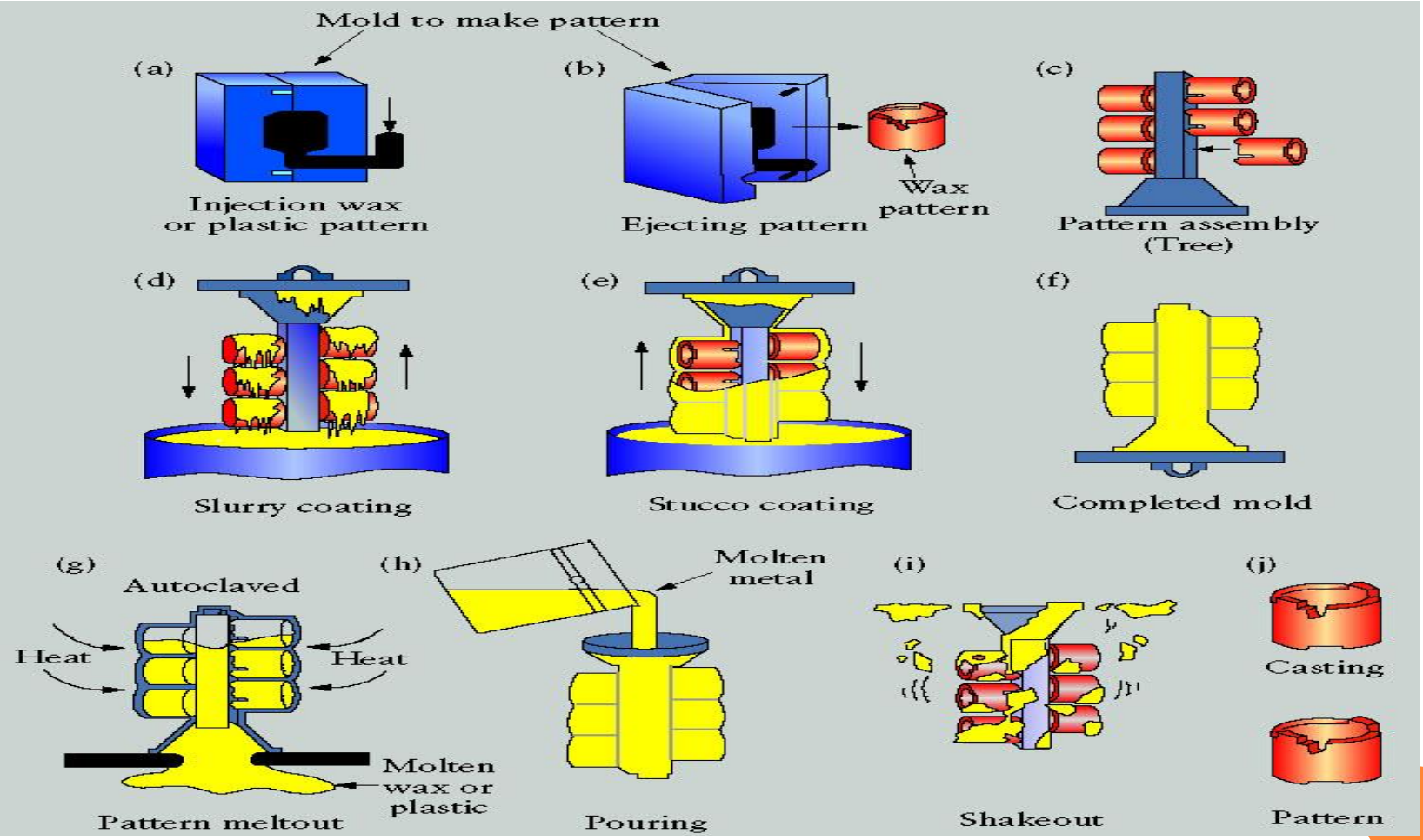
Manufacturing Technology

Process Steps in Detail

1. Wax Pattern made.
2. Patterns attached to wax sprue.
3. Pattern tree coated with thin layer of refractory material.
4. Pattern tree coated with sufficient refractory material.
5. Invert tree and melt wax by heat.
6. Preheat mold to high temperature to induce flow and remove contaminants.
7. Mold broken and parts remove.

Manufacturing Technology

- Example - 2



Manufacturing Technology

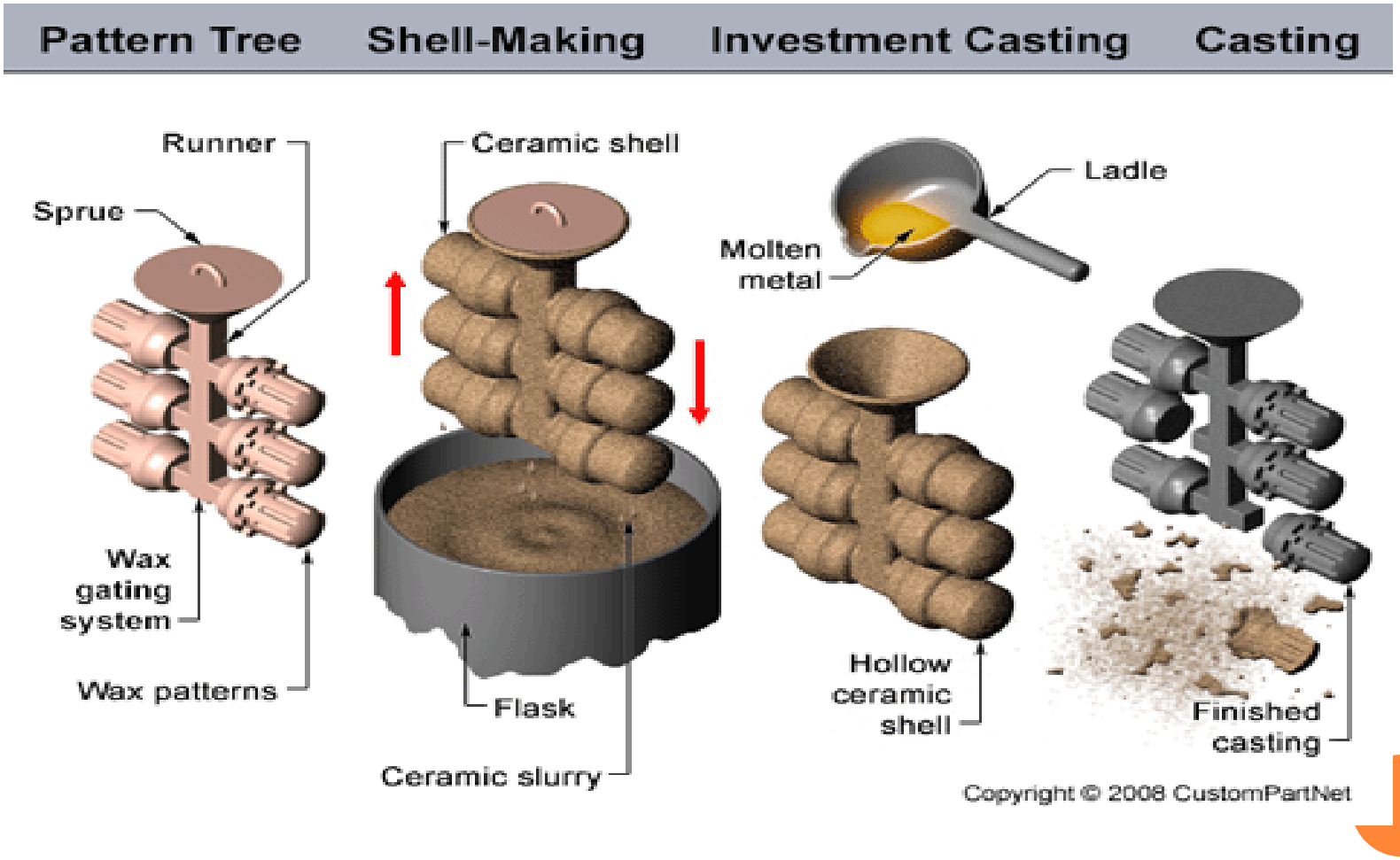
- Process Steps in Detail
  - Produce a master pattern
  - Produce a master die
  - Produce wax patterns
  - Assemble the wax patterns onto a common wax sprue
  - Coat the tree with a thin layer of investment material
  - Form additional investment around the coated cluster
  - Allow the investment to harden

Manufacturing Technology

- Remove the wax pattern from the mold by melting or dissolving
- Heat the mold
- Pour the molten metal
- Remove the solidified casting from the mold

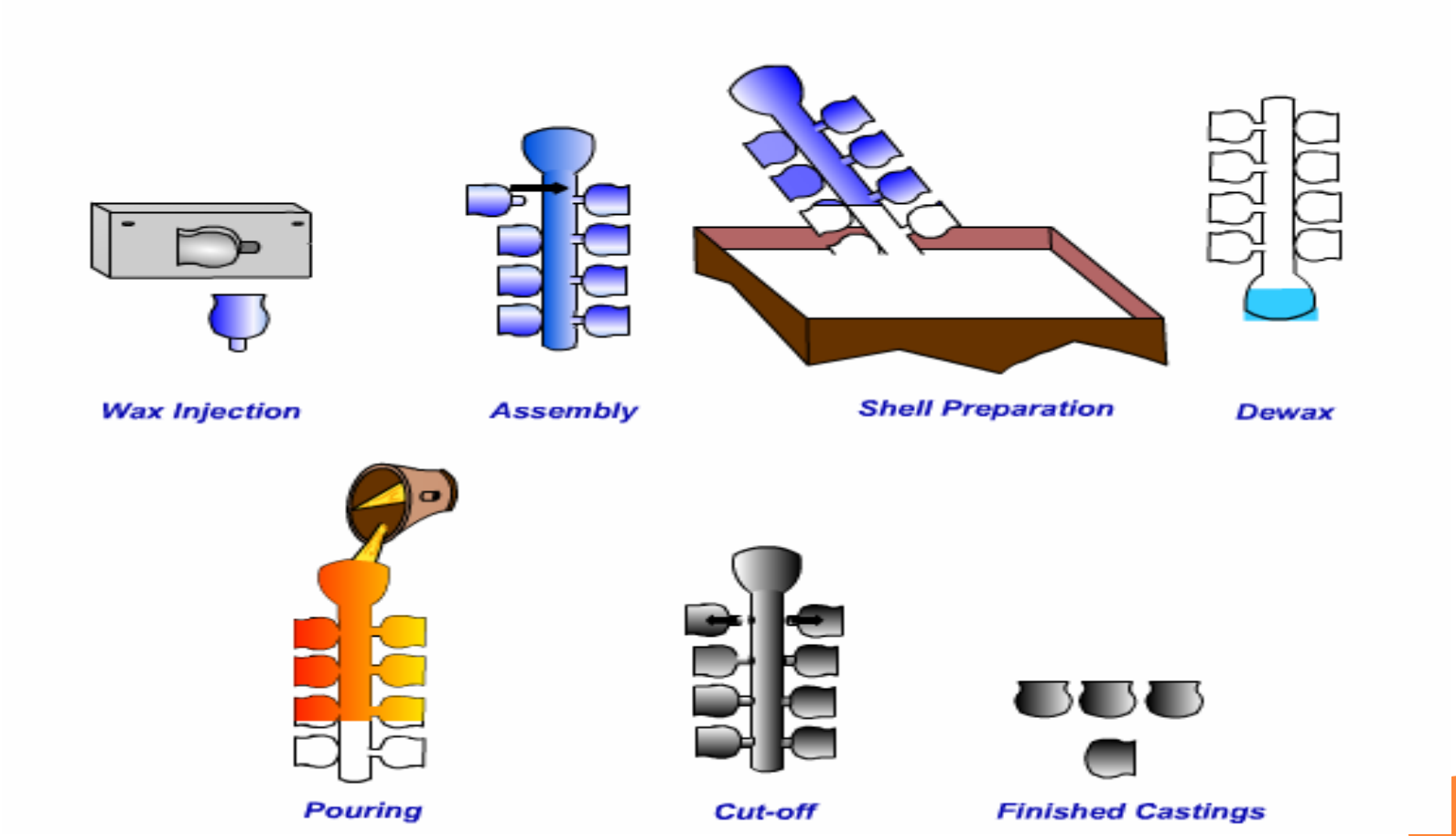
Manufacturing Technology

- Example - 3



Manufacturing Technology

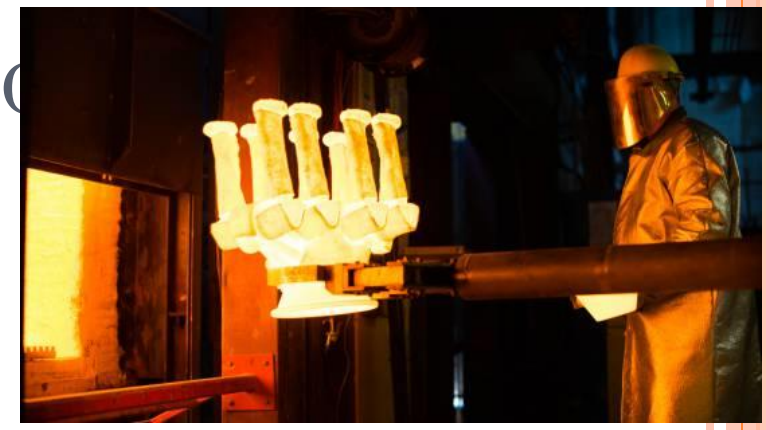
- Example - 4



Manufacturing Technology

- *Advantages*
  - Excellent accuracy and flexibility of design.
  - Useful for casting alloys that are difficult to machine.
  - Exceptionally fine finish.
  - Suitable for large or small quantities of parts.
  - Suitable for most ferrous / non-ferrous metals.
  - Complex shapes can be cast
  - Thin sections can be cast
  - Machining can be eliminated or reduced
- *Disadvantages*
  - Limitations on **size of casting**.
  - **Higher casting costs** make it important to take full advantage of the process to **eliminate all machining** operations.

Manufacturing Technolo



- *Area of application*
  - One of the oldest casting methods
  - complex parts such as **art pieces, jewelry**, **dental fixtures** from all types of metals.
  - Products such as **rocket components**, and **jet engine turbine blades**

Manufacturing Technology

Permanent Mold Casting

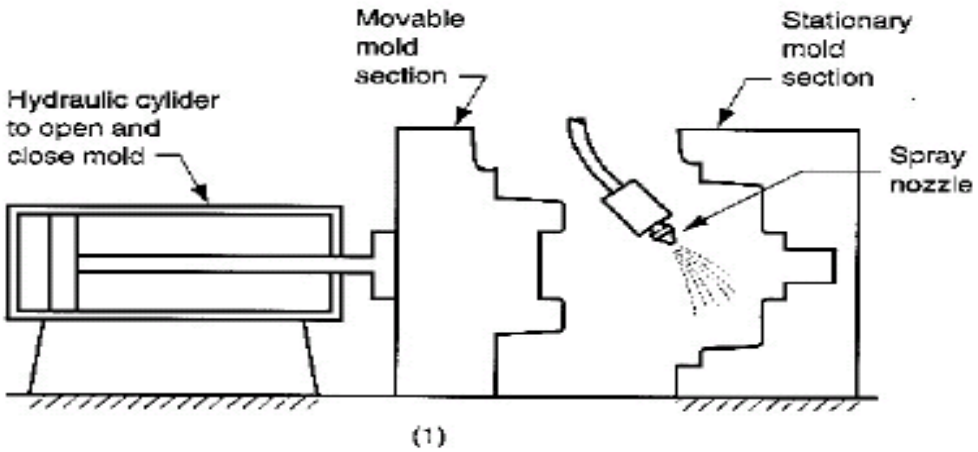
- In Permanent Molding Process, instead of using sand as the mold material, a **metal is used as a mold** (**Die**).
  - **In contrary to sand casting**, in permanent mold casting the mold is used to produce **not a single but many castings**.
- In all the above processes, a **mold need to be prepared for each of the casting** produced. For **large-scale production**, making a mold, for every casting to be produced, may be **difficult and expensive**.
- Therefore, a **permanent mold, called the die** may be made from **iron or steel, although graphite, copper** and **aluminum** have been used as mold materials.

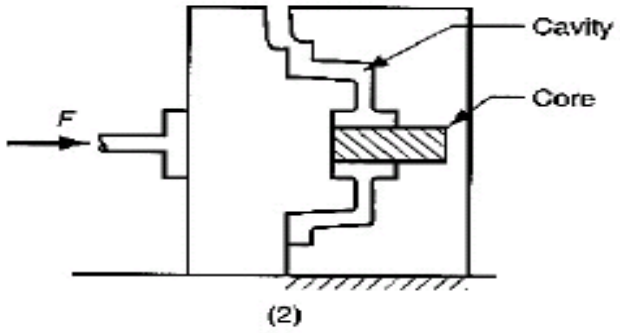
Manufacturing Technology

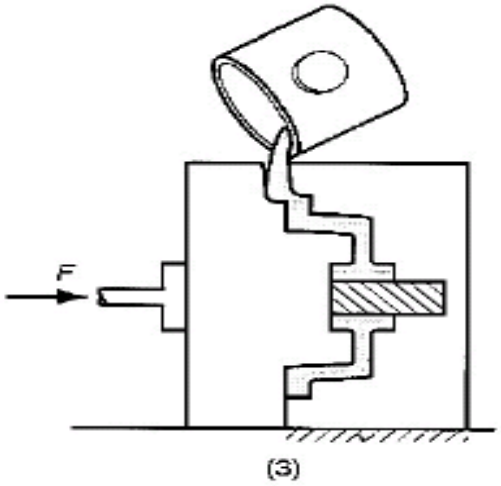
- The process in which **we use a die** to make the castings is called **permanent mold casting or gravity die casting**, since the **metal enters the mold under gravity**.
- Some time in die – casting, we **inject the molten metal with a high pressure**. When we apply pressure in injecting the metal it is called **pressure die casting** process.
- Permanent mold casting is typically used for **high-volume production** of small, simple metal parts with **uniform wall thickness**.

Permanent Mold Casting

- Processing Steps



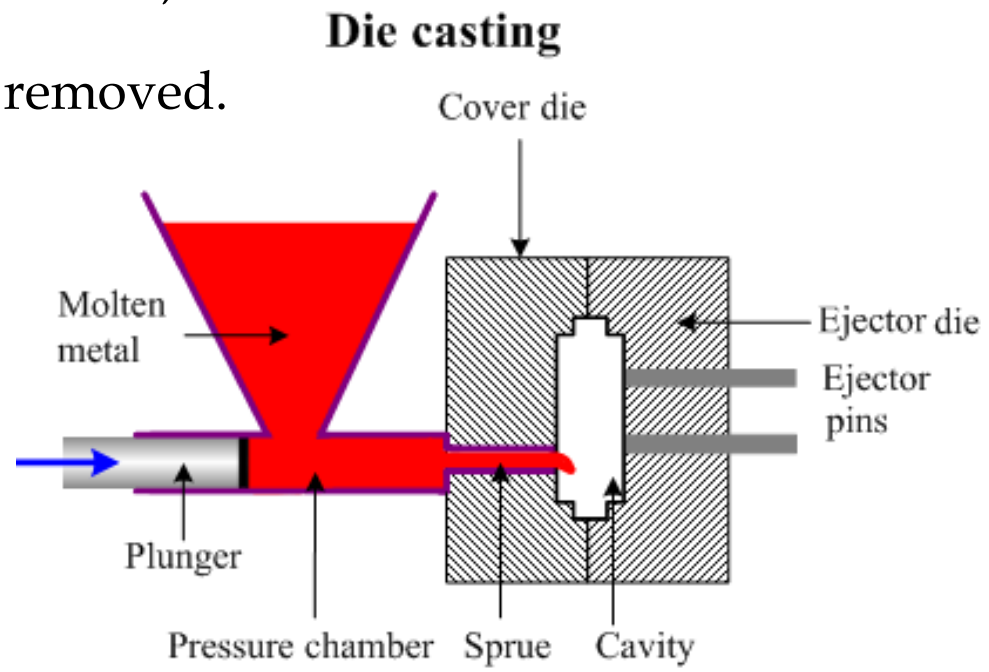




Permanent Mold Casting

Process Steps in Detail

1. **Mold is preheated and coated with lubricant** for easier separation of the casting;
2. Cores (if used) are inserted and mold is closed;
3. **Molten metal is poured** into the mold;
4. Mold is open and finished part removed.
5. Processing Finished part



Manufacturing Technology

- *Advantages*
  - Good dimensional accuracy
  - Good surface finish
  - Finer grain structure (stronger casting)
  - Possibility for automation
- *Disadvantages*
  - Only for metals with low melting point
  - Castings with simple geometry
- *Area of application*
  - Mass production of non-ferrous alloys and cast iron

Manufacturing Technology

Die casting

- Die casting is a very commonly used type of permanent mold casting process.
- It is used for producing many components of home appliances.
  - Rice cookers, fans, washing & drying machines.
  - Stoves, fridges, motors and toys
  - Hand-tools.
- Surface finish and tolerance of die cast parts is so good that there is almost **no post-processing required**. Die casting molds are **expensive**, and require **significant lead time** to fabricate.

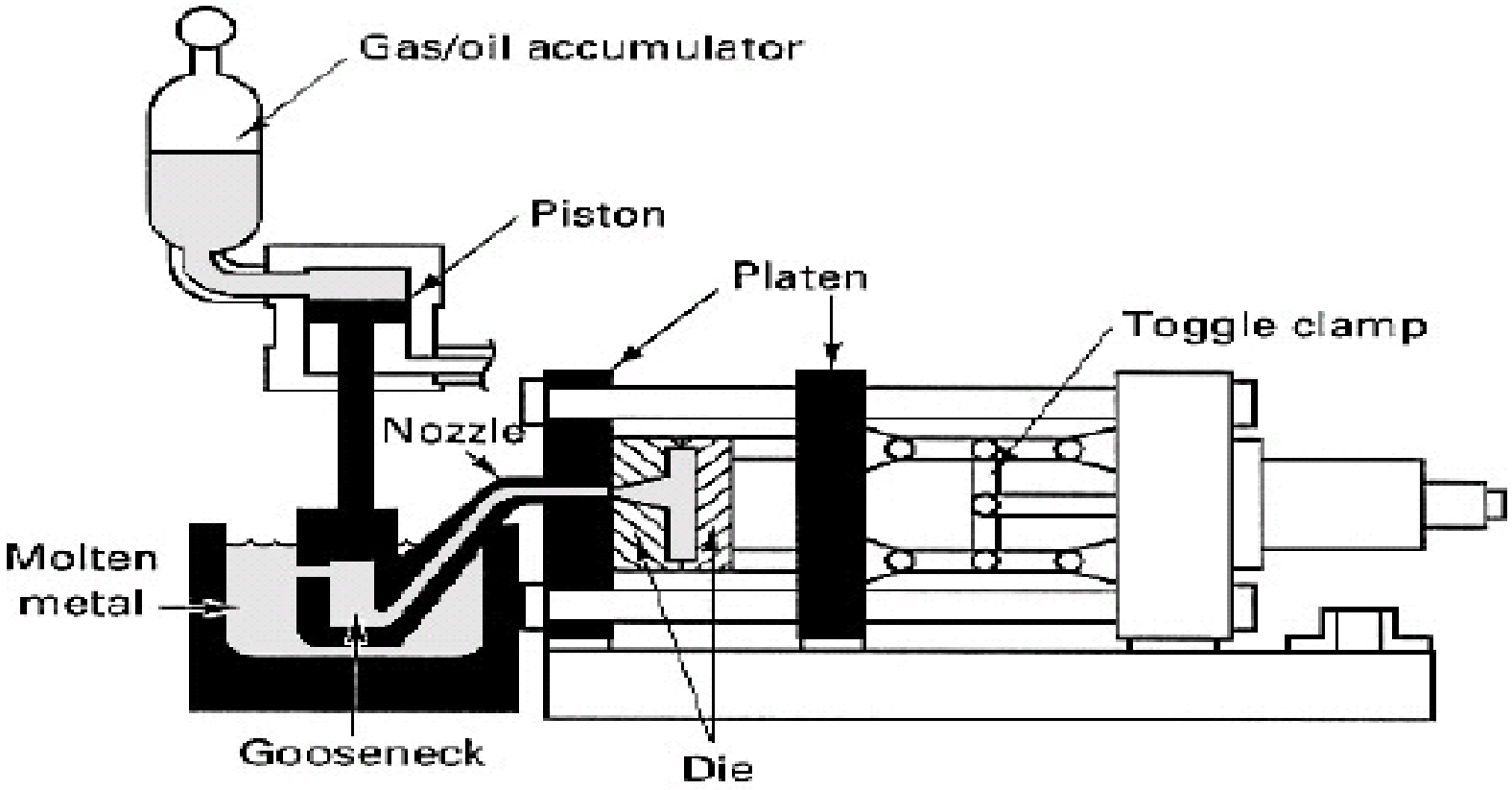
Manufacturing Technology

Types of Die Casting

- Hot-chamber die-casting
  - In hot chamber die-casting, the **metal is melted in a container attached** to the machine, and a piston is used to **inject the liquid metal** under high pressure into the die.
- Cold chamber die casting
  - In cold-chamber die-casting, **molten metal is poured into the chamber** from an **external melting container**, and a piston is used to inject the metal under **high pressure into the die cavity**.

Manufacturing Technology

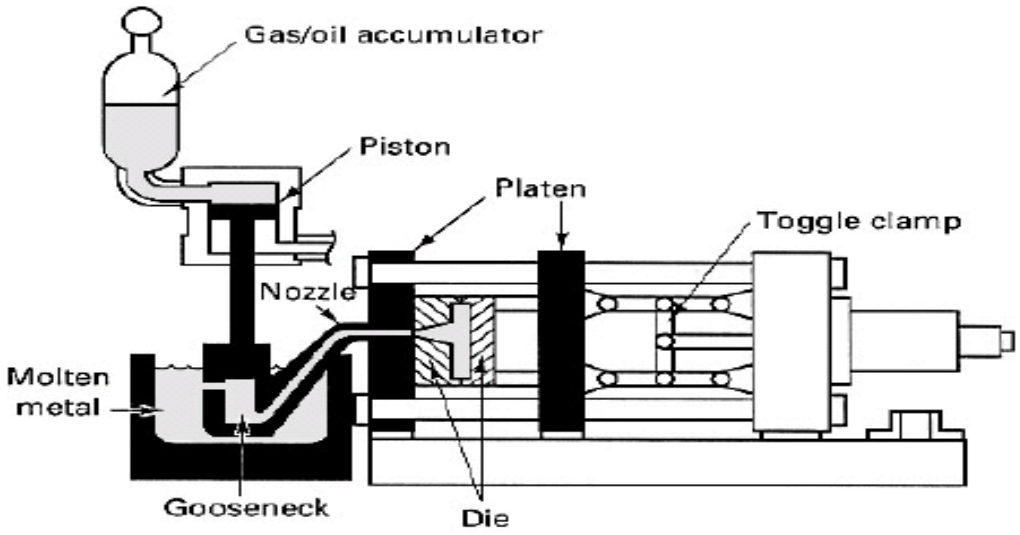
Hot-chamber die-casting



Schematics of Hot-chamber die-casting

Hot-chamber die-casting Process Details

- In a hot chamber process (used for **Zinc alloys, magnesium**) the pressure chamber connected to the die cavity is filled permanently in the molten metal
- **Die is closed** and **gooseneck cylinder is filled** with molten metal;
- Plunger pushes **molten metal through gooseneck passage** and nozzle and into the die cavity; metal is held **under pressure until it solidifies**.
- Die opens and cores, if any, are retracted; casting stays in ejector die; plunger returns, pulling molten metal back through nozzle and gooseneck;
- **Ejector pins push casting** out of ejector die. As plunger uncovers inlet hole, molten metal refills gooseneck cylinder.



Manufacturing Technology

Advantages

- High productivity (**up to 500 parts per hour**)
- Close tolerances
- Good surface finish

Disadvantages

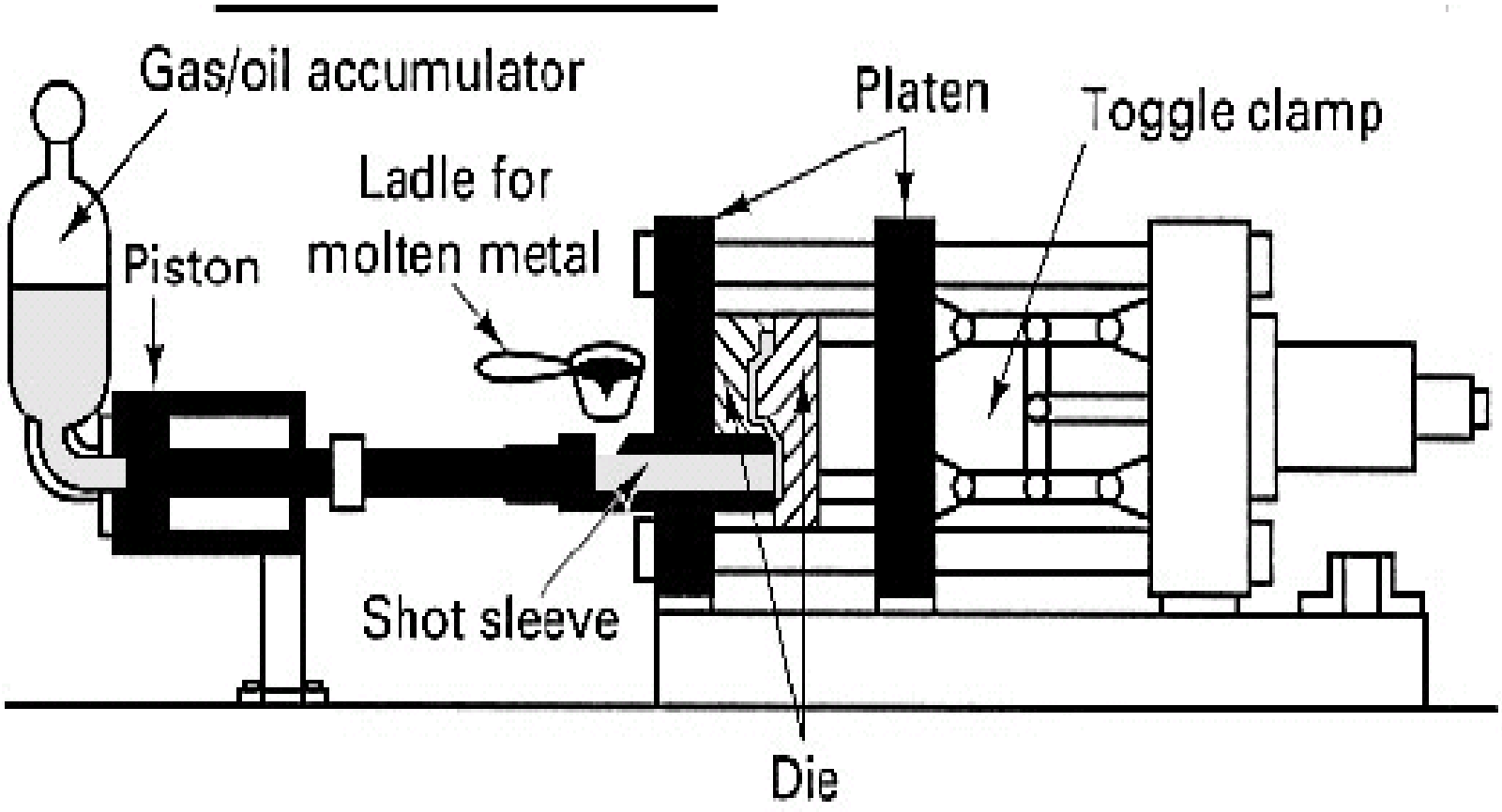
- The **injection system is submerged** in the molten metal
- Only simple shapes

Area of application

- Mass production of non-ferrous alloys with very low melting point (zinc, tin, lead)

Manufacturing Technology

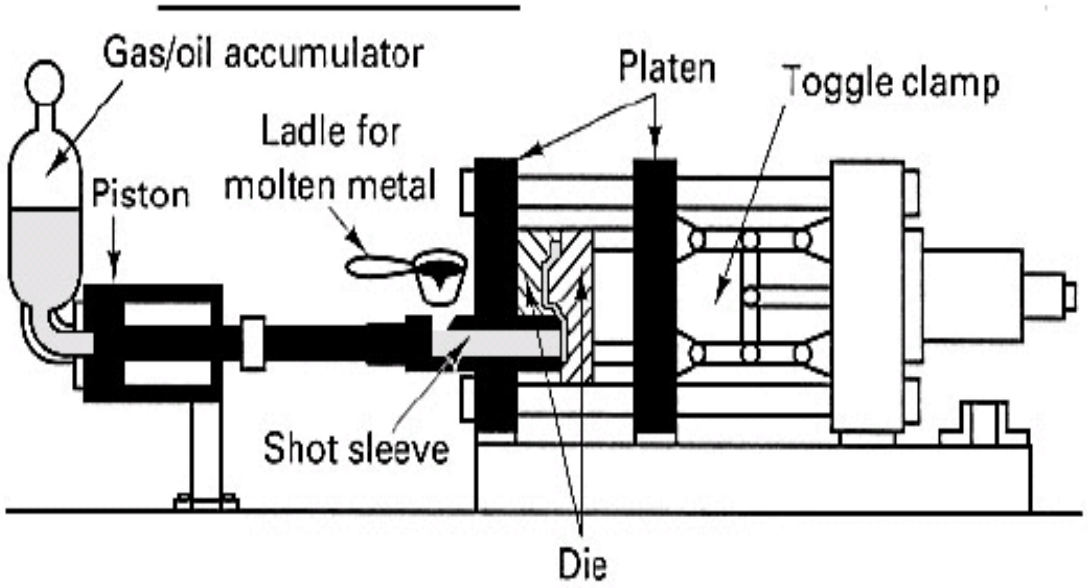
Cold chamber die casting



Schematics of Cold-chamber die-casting

Cold chamber die casting Process details

- In a cold chamber process, the molten metal is poured into the cold chamber in each cycle
- Die is closed and **molten metal is ladled** into the cold chamber cylinder;
- Plunger pushes molten metal into die cavity; the metal is held under high pressure until it solidifies;
- Die opens and **plunger follows to push the solidified slug** from the cylinder, if there are cores, they are retracted away;
- **Ejector pins push casting off** ejector die and plunger returns to original position.



Manufacturing Technology

Advantages

- Same as in hot chamber die-casting, but less productivity.

Disadvantages

- Only simple shapes

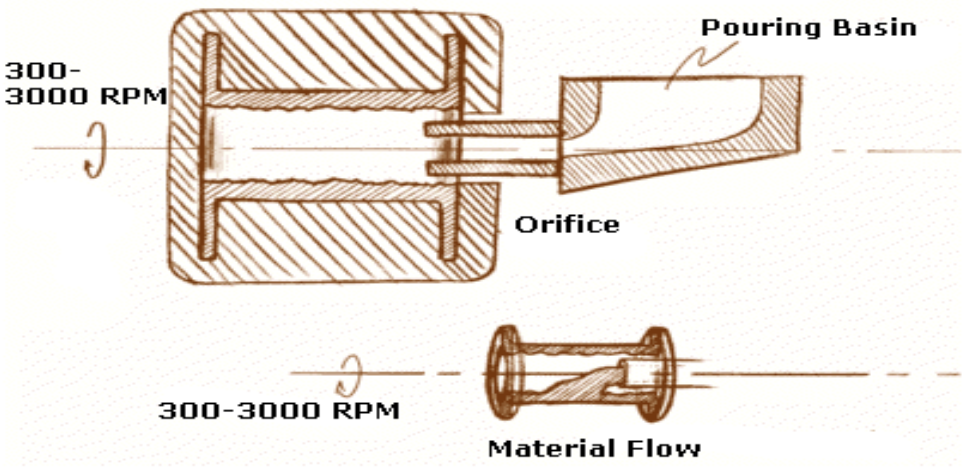
Area of application

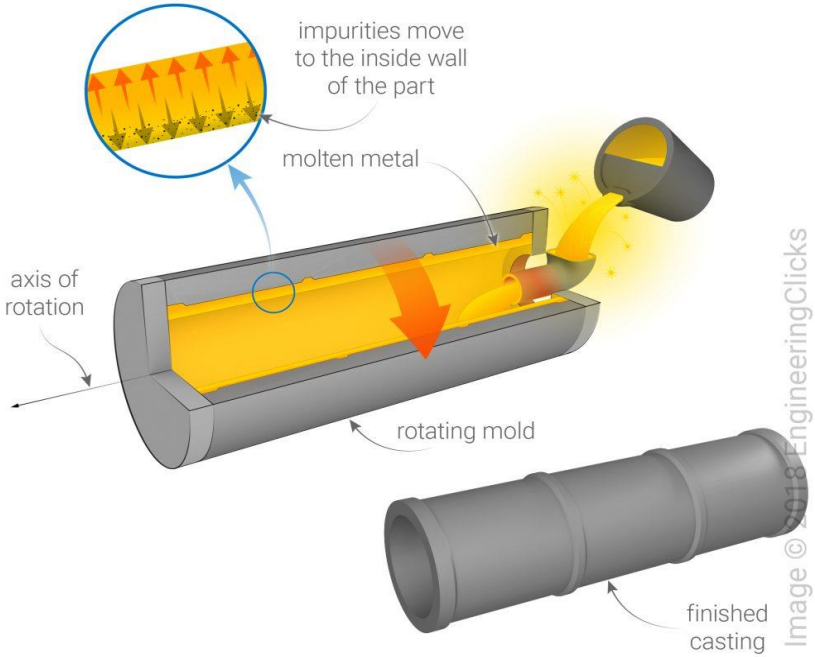
- Mass production of aluminium and magnesium alloys, and brass

Manufacturing Technology

Centrifugal casting

- Centrifugal casting uses a permanent mold that is rotated about its axis at a **speed between 300 to 3000 rpm** as the molten metal is poured. Centrifugal forces cause the **metal to be pushed out towards the mold walls**, where it solidifies after cooling





Manufacturing Technology

- This process is normally used for the **making of hollow pipes, tubes, hollow bushes**, etc., which are **axi-symmetric with a concentric hole**.
- Since the metal is always pushed outward because of the centrifugal force, **no core needs to be used** for making the concentric hole.
- The mold can be rotated about a **vertical, horizontal or an inclined axis** or about its horizontal and vertical axes simultaneously.
- The **length and outside diameter are fixed** by the mold cavity dimensions while the inside diameter is determined by the **amount of molten metal poured into the mold**.

Manufacturing Technology

Types

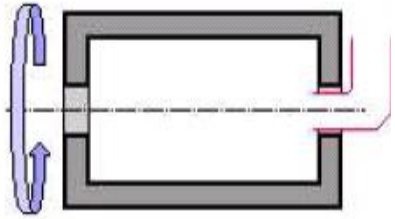
- Horizontal Centrifugal Casting
- Vertical Centrifugal Casting

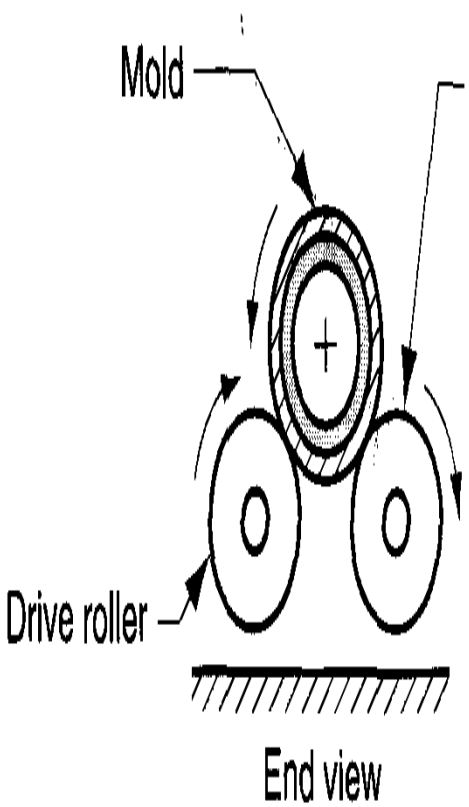
Horizontal Centrifugal Casting

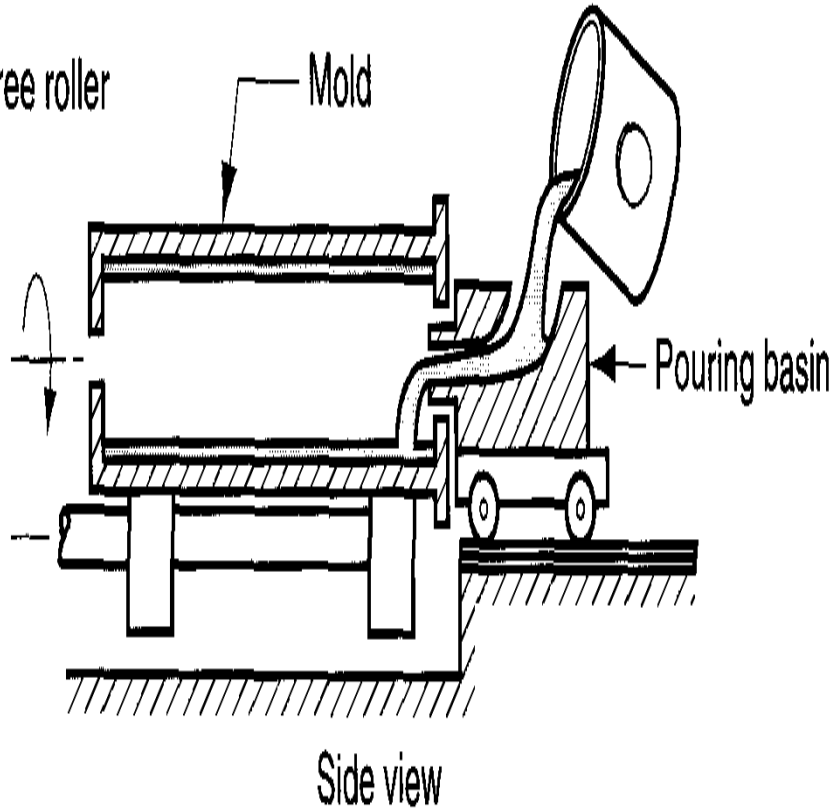
- True centrifugal casting
- In this casting, molten metal is poured into a rotating mold to produce tubular parts such as pipes, tubes, and rings

Manufacturing Technology

Horizontal Centrifugal Casting







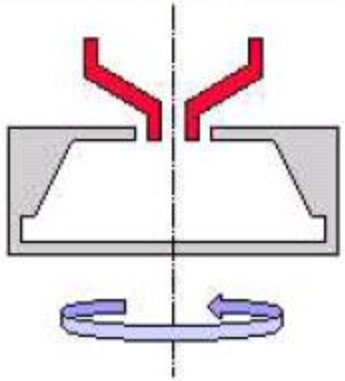
Manufacturing Technology

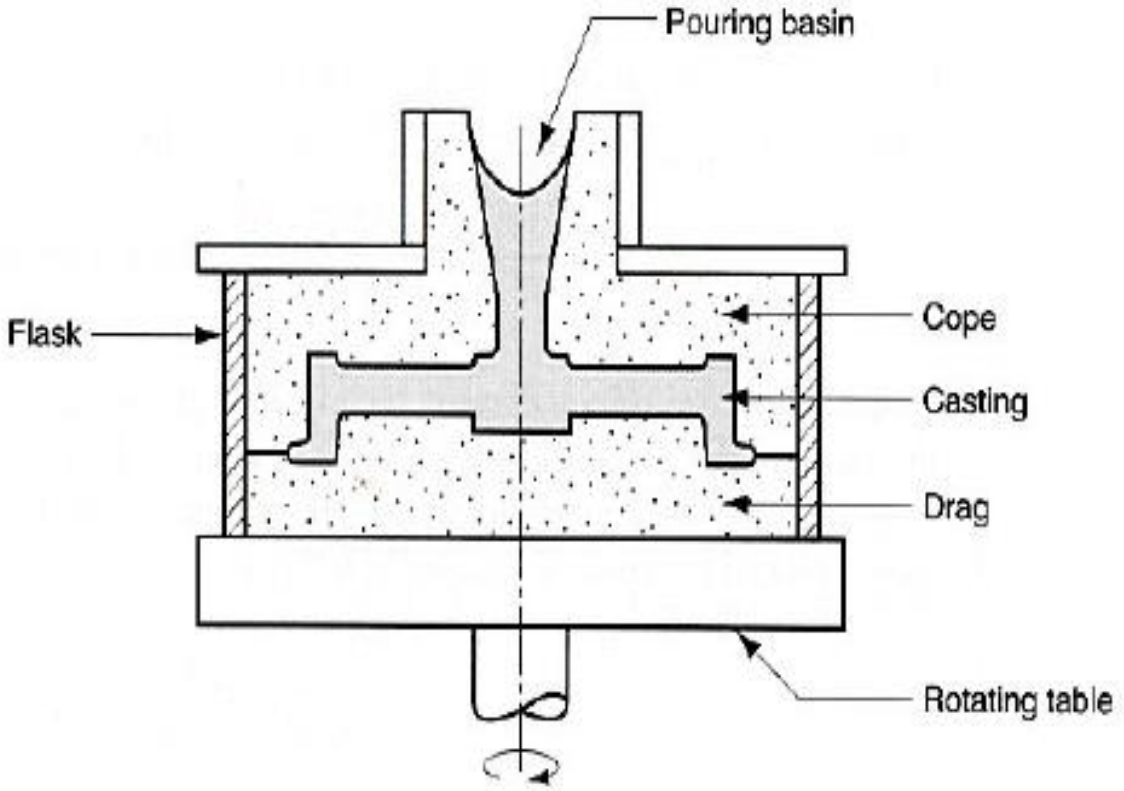
Vertical Centrifugal Casting

- In this method, centrifugal force is used to **produce solid castings** rather than tubular parts.
- Density of the metal in the final casting is greater in the outer sections than at the center of rotation.
- The process is used on parts in which the center of the casting is machined away, such as wheels and pulleys.

Manufacturing Technology

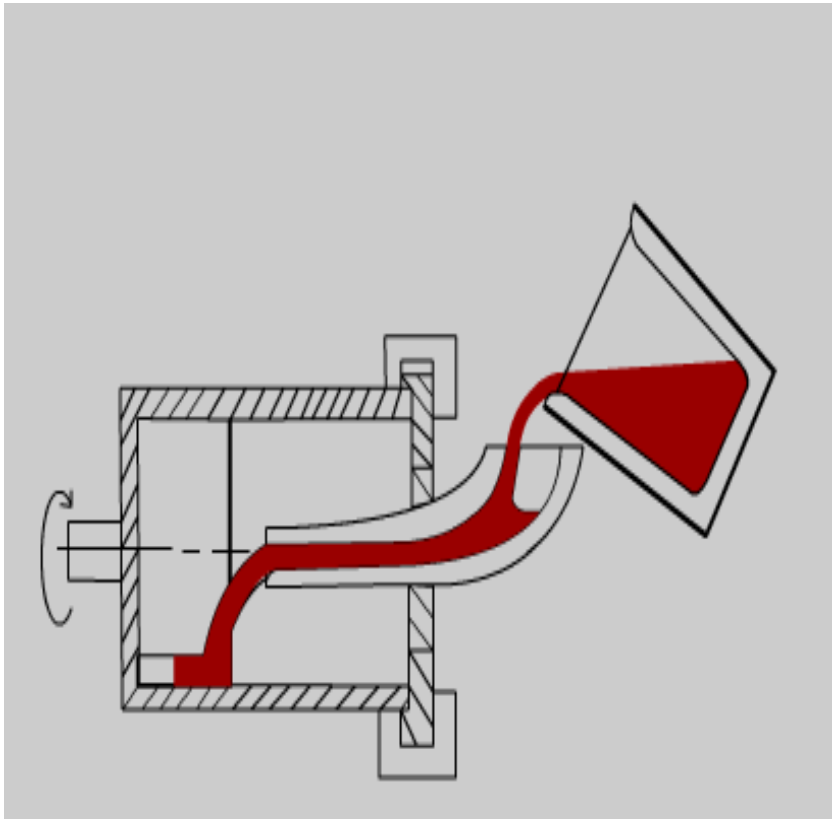
Vertical Centrifugal Casting



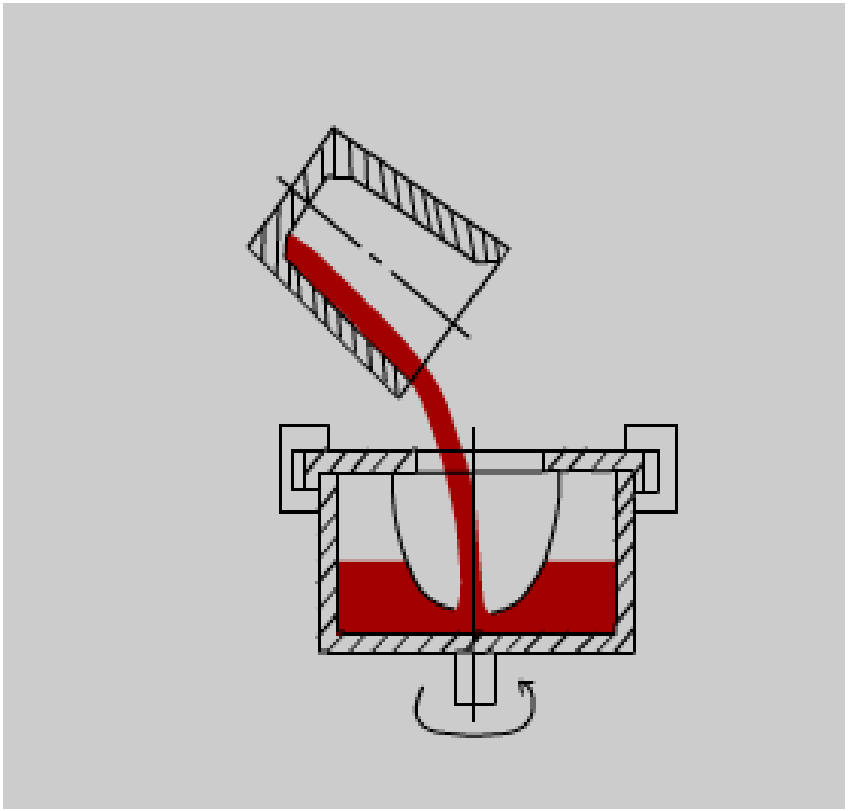


Manufacturing Technology

Centrifugal Casting



Horizontal Centrifugal Casting



Vertical Centrifugal Casting

Manufacturing Technology

Advantages

- **Rapid production** rate.
- Suitable for Ferrous / Non-ferrous parts.
- Good soundness and cleanliness of castings.
- Ability to produce **extremely large cylindrical** parts.
- Formation of **hollow interiors in cylinders without cores**
- **Fine grained structure** at the outer surface of the casting **free of gas and shrinkage cavities** and **porosity**

Manufacturing Technology

Disadvantages

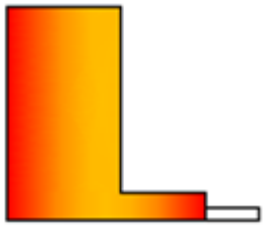
- **More segregation of alloy** component during pouring under the forces of rotation
- **Contamination of internal surface** of castings with non - metallic inclusions
- Inaccurate internal diameter
- **Only cylindrical shapes** can be produced with this process.

Application

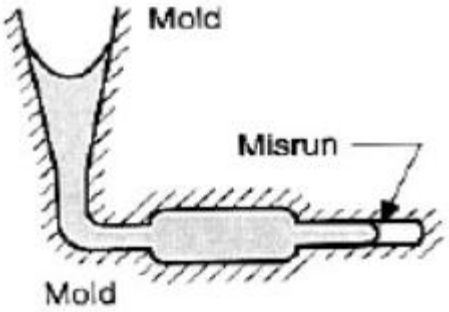
- Pipe and Tube Manufacturing

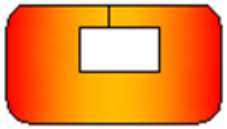
Casting Defects

- There are **numerous opportunities** in the casting operation for **different defects** to appear in the cast product. Some of them are **common to all casting** processes:
- *Misruns*: Casting **solidifies before completely** fill the mold. Reasons are **low pouring temperature**, **slow pouring** or thin cross section of casting.
- *Cold shut:* Two portions flow together but **without fusion** between them. Causes are **similar to those of a misrun**.

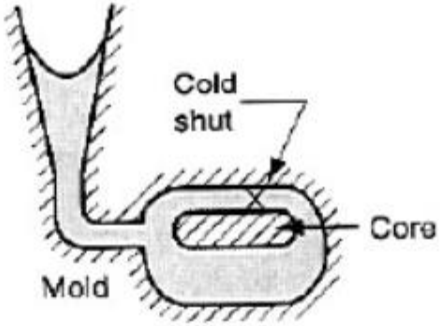


Misrun





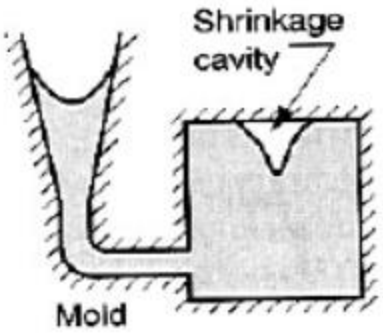
Cold shut

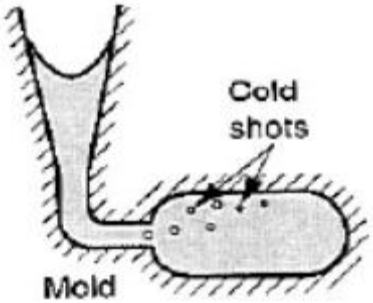


Casting Defects

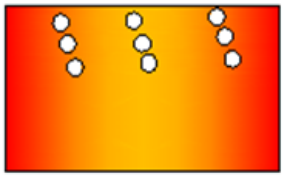
- *Shrinkage cavity:* **Voids resulting from shrinkage**. The problem can often be solved by **proper riser design** but may require some changes in the part design as well.
- *Cold shots:* When **splattering occurs** during pouring, **solid globules of metal** are **entrapped** in the casting. **Proper gating** system designs could avoid this defect.
- *Micro-porosity:* Network of **small voids distributed** throughout the casting. The defect occurs **more often in alloys**, because of the manner they solidify.

Shrinkage Cavity

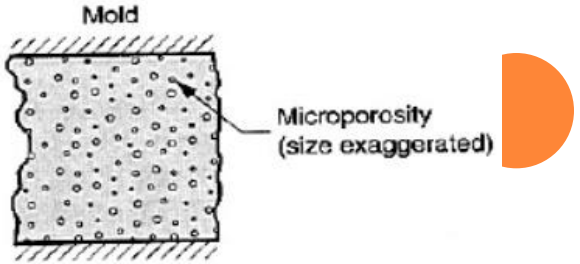




Blowholes



Pinholes



Casting Defects

- *Hot tearing:* **Cracks caused by low mold collapsibility**. They occur when the **material is restrained** from **contraction during solidification**. A proper mold design can solve this problem.