SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
An Autonomous Institution

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DEPARTMENT OF MECHANICAL ENGINEERING

19MEZ405- CASTING DESIGN AND PERFORMANCE

IV YEAR / VIII SEM

UNIT – 2

CASTING DESIGN PRINCIPLES AND PRACTICES

UNIT I CASTING PROCESS

Casting Process - Classification, characteristics of sand casting processes, metal mould casting processes and casting processes using other mould/core materials, Pattern materials, types of patterns, Mould and core making materials and their characteristics. The features of casting problem; a survey and scope of foundry industry

UNIT II CASTING DESIGN PRINCIPLES AND PRACTICES

Casting Design Issues and Practices - Casting Design and Processes -Modeling of Casting and Solidification Processing - Solidification of pure metals and al1oys; nucleation and growth in alloys; solidification of actual castings; progressive and directional solidification; centre in feeding resistance; rate of solidification, electrical analog of solidification problems

UNIT III PROCESS DESIGN

Process Design - Pattern design - Riser Design - Gating Design - Design for Economical Sand Molding - Design for Economical Coring – Moulding and Core Making Processing

UNIT IV CASTING DESIGN AND GEOMETRY

Design Problems Involving - Thin Sections - Design Problems Involving Uniform Sections - Design Problems Involving Unequal Sections - Design Problems Involving Junctions - Design Problems Involving Distortion

UNIT V CASTING PERFORMANCE

Corrosion of Cast Irons - Corrosion of Cast Carbon and Low-Alloy Steels - Corrosion of Cast Stainless Steels - Fatigue and Fracture Properties of Cast Irons - Fatigue and Fracture Properties of Cast Steels - Fatigue and Fracture Properties of Aluminum -Alloy Castings - Friction and Wear of Cast Irons - Friction and Wear of Aluminum-Silicon Alloys - Failure Analysis of Castings . Inspection of Castings

CASTING DESIGN ISSUES AND PRACTICES

Casting is a crucial manufacturing process where a material is poured into a mold to take shape once it solidifies. However, successful casting design requires addressing several key issues and adhering to best practices for optimal outcomes.

Casting Design Issues and Practices

1. **Material Selection**: Choosing the right material ensures desired mechanical properties and compatibility with the casting process.
2. **Mold Design**: Molds must be designed to withstand high temperatures and pressure while ensuring smooth material flow.
3. **Wall Thickness**: Uniform wall thickness helps avoid defects like warping, shrinkage, or cracks during cooling.
4. **Gate and Runner Design**: Proper gate and runner systems help control the flow of molten metal, minimizing defects like cold shuts and air entrapment.
5. **Solidification Rate**: Controlling the cooling rate is critical to preventing defects such as porosity, cracks, and uneven surface finishes.
6. **Tolerance and Finish**: Designing for desired dimensional accuracy and surface finish to minimize post-casting machining.
7. **Cost Efficiency**: Balancing design complexity with cost is important, as intricate molds and additional processes increase production costs.

By carefully addressing these issues, manufacturers can achieve high-quality castings that meet design specifications.

Metal Casting Modeling

1. **Design & Planning**: Create a 3D model using CAD, then select the appropriate material (e.g., aluminum, steel).
2. **Pattern Making**: Fabricate a pattern (replica of the final casting) slightly larger to account for shrinkage.
3. **Mold Making**: Surround the pattern with mold material (e.g., sand or ceramic) and harden it.
4. **Core Making** (if needed): Create internal cores for cavities.
5. **Metal Melting**: Melt the metal in a furnace, adding any required alloys.
6. **Pouring the Metal**: Pour molten metal into the mold carefully.
7. **Cooling & Solidification**: Allow the metal to cool and solidify.
8. **Mold Removal**: Break or dissolve the mold to extract the casting.
9. **Finishing & Inspection**: Clean the casting, inspect for defects, and apply any necessary post-casting treatments.
10. **Machining**: Perform final machining for dimensions and surface finish.

Solidification of pure metals

Solidification is the process by which molten metal cools and transitions from a liquid to a solid state. The behavior of solidification differs between pure metals and alloys, impacting the final properties of the castings.

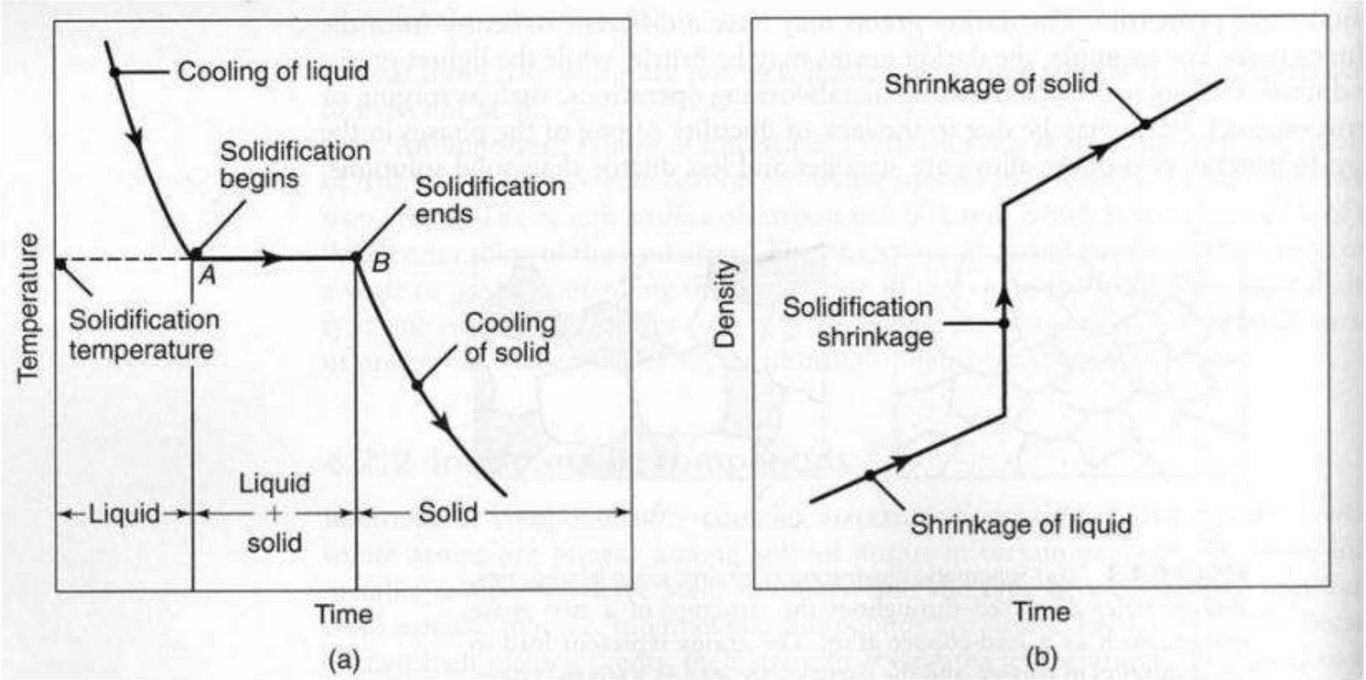
1. Solidification of Pure Metals

•**Freezing Point**: Pure metals have a **distinct freezing point**, meaning they solidify at a single temperature. As the molten metal cools, it starts to crystallize at this temperature.

•**Crystal Formation**: Pure metals tend to form a **single crystalline structure** throughout the casting. The metal solidifies in a **uniform, orderly pattern** from the outer surface toward the center.

•**Solidification Shrinkage**: Pure metals experience shrinkage as they solidify, but the process is relatively straightforward since there is only one phase (solid phase) involved.

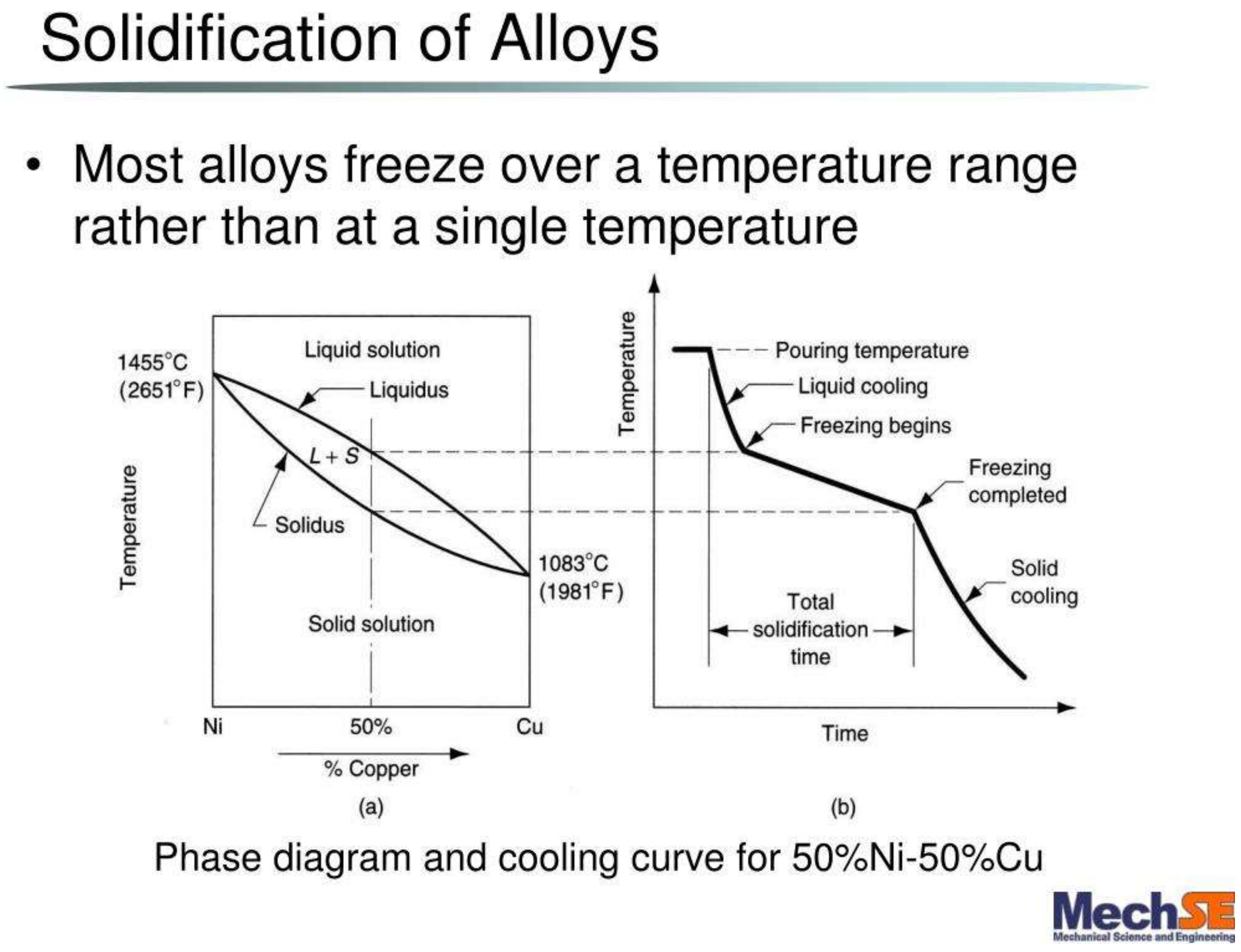
Solidification of Pure Metals



Pure metals solidify at a constant temperature. During freezing the latent heat of solidification is given off. Most metals shrink on solidification and shrink further as the solid cools to room temperature.

Solidification of Alloys

•**Freezing Range**: Unlike pure metals, **alloys** have a **freezing range**—a temperature range over which both liquid and solid phases coexist. This occurs because alloys are mixtures of two or more metals, which have different melting points.
•**Eutectic Point**: In some alloys, such as eutectic alloys, there is a specific composition and temperature (the **eutectic point**) at which the alloy solidifies at a single temperature. At this point, the alloy solidifies as a mixture of two distinct solid phases.
•**Dendritic Growth**: During solidification, **dendrites** (tree-like structures) form as the liquid metal cools. The solidification of alloys is often more complex, leading to different microstructures and phases, depending on the alloy composition and cooling rate.
•**Segregation**: Alloy solidification can lead to **segregation**, where different elements in the alloy concentrate in certain areas, causing variations in composition and properties within the casting.



Nucleation and Growth in Alloys

1.Nucleation:

1. **Definition**: The process where small clusters of atoms (nuclei) form in the molten metal, initiating solidification.
2. **Types**:
   1. **Homogeneous**: Nuclei form spontaneously within the liquid (rare).

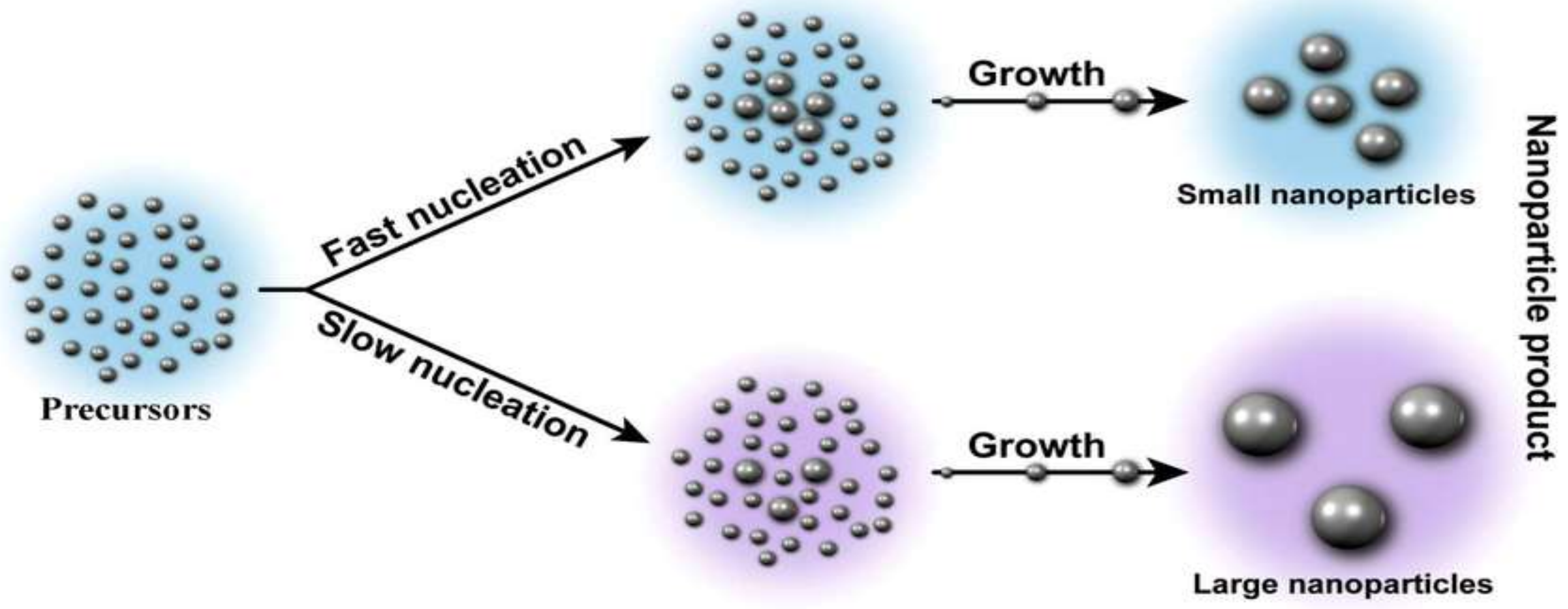
   Heterogeneous: Nuclei form on impurities or mold surfaces (more common in casting).
3. **Impact**: Faster nucleation leads to finer grains and improved strength.

Growth:

•**Definition**: The process where the formed nuclei expand as the liquid solidifies.

•**Dendritic Growth**: Solid forms tree-like branches (dendrites), affecting the material's structure.

•**Impact**: Faster cooling results in smaller dendrites, while slower cooling promotes larger ones, affecting the material's properties.



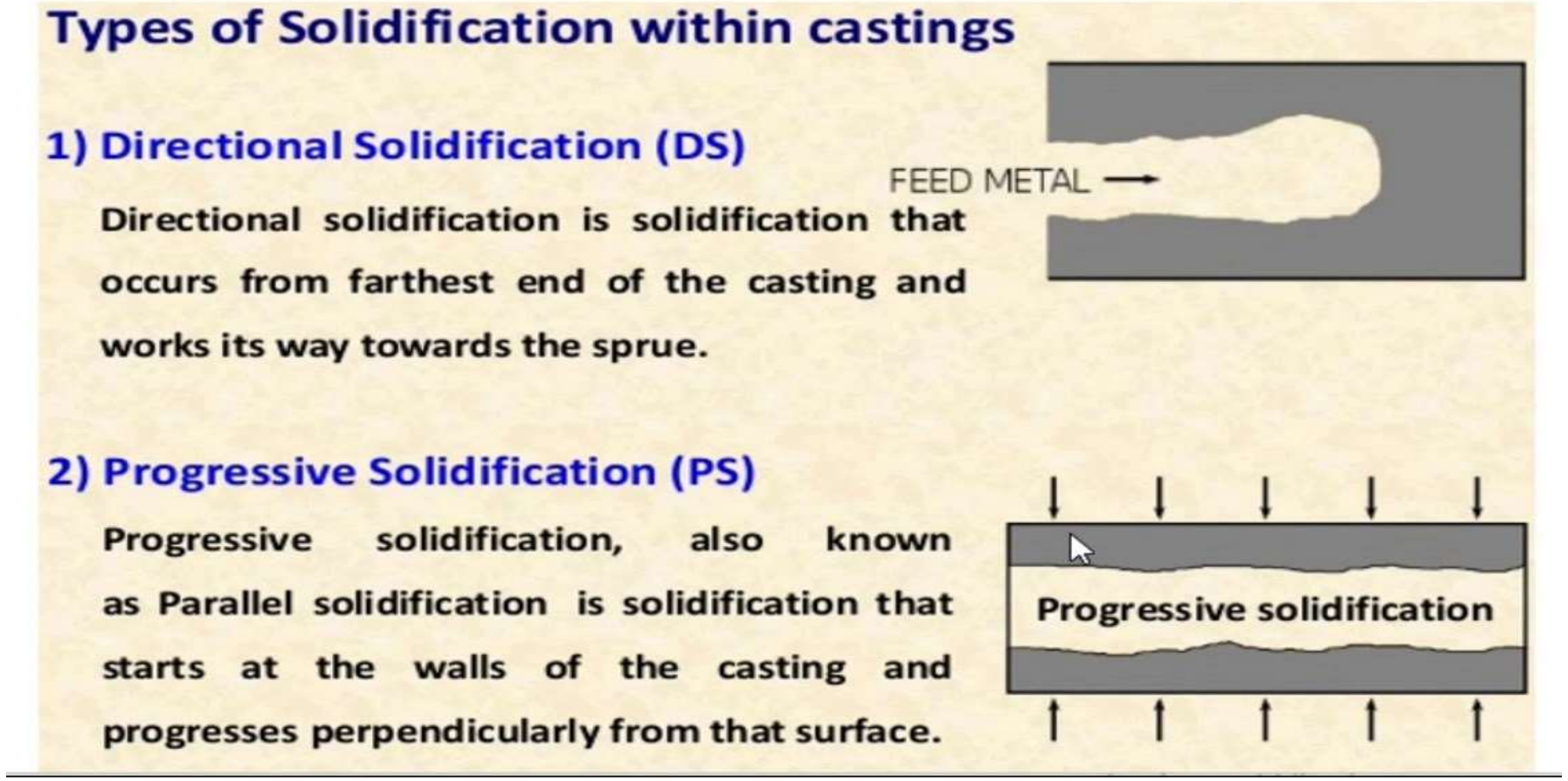
Solidification of Actual Casting

•**Definition**: The process of transforming molten metal into a solid state after pouring into a mold.

•**Process**: The metal cools from the surface towards the center. Solidification begins at the mold surface and gradually moves inward.

•**Factors**:

- Heat transfer rate between the mold and metal.
- Thermal conductivity of the material.
- Mold material and design.



Directional Solidification

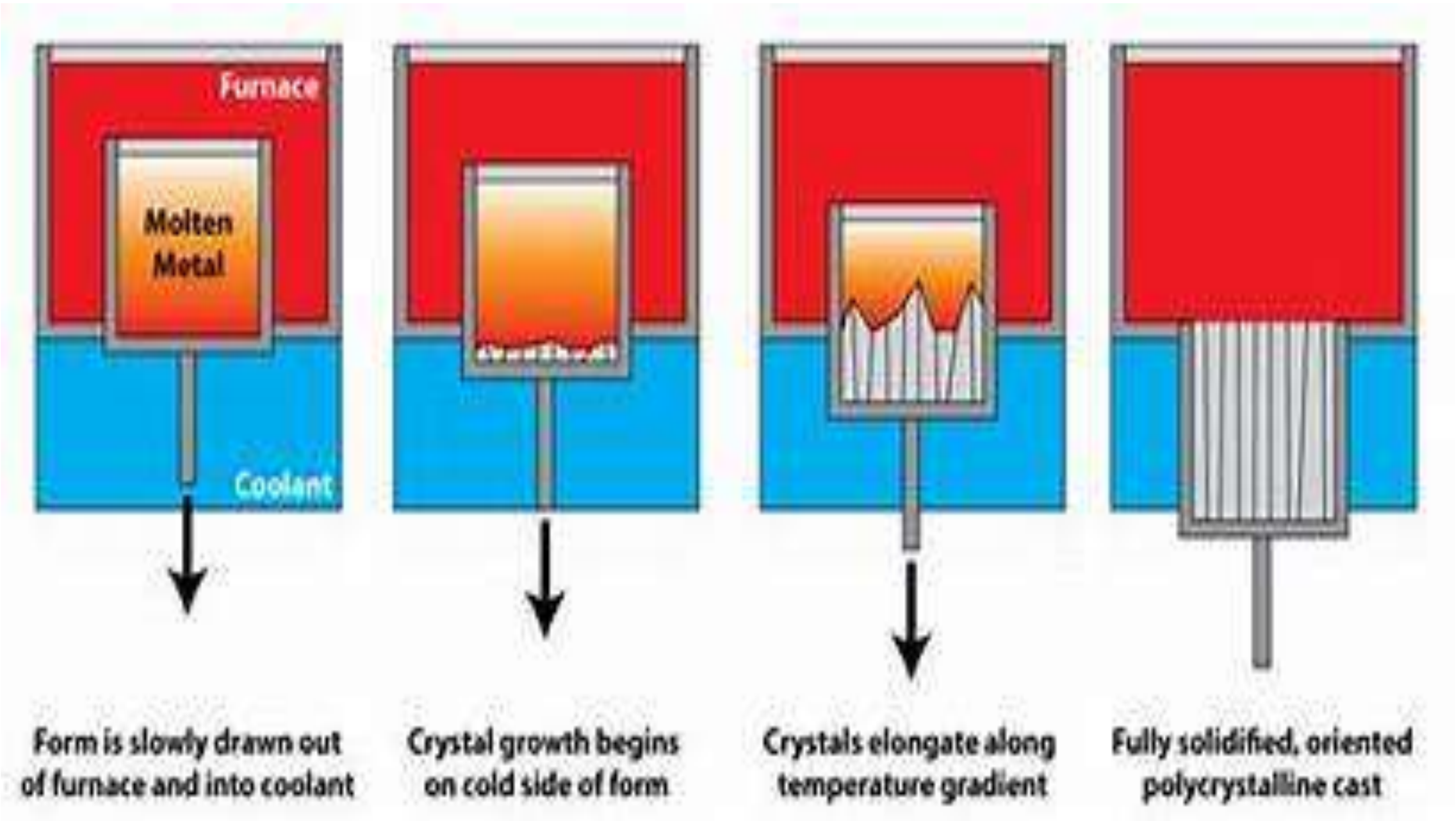
•**Definition**: A controlled solidification process where the molten metal solidifies in a specific direction, typically from the cooler outer regions toward the hotter center.

•**Advantages**:

- Reduces defects like porosity and shrinkage.
- Enhances the mechanical properties by ensuring the grains align properly.

•**Methods**:

- Use of chills or heat sinks to control cooling rate.
- Shaping mold design to encourage solidification from one direction (typically the bottom of the mold upwards).



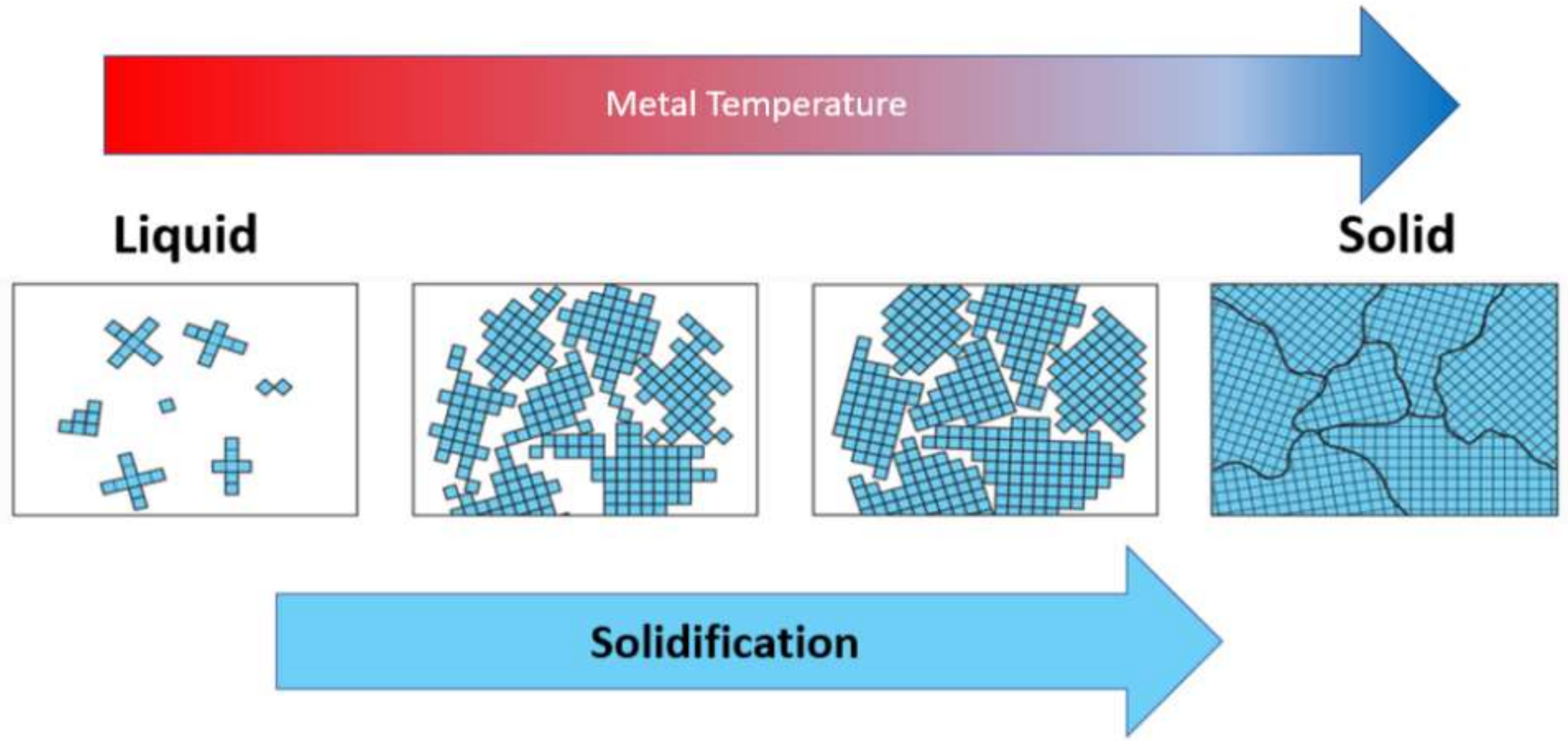
Progressive Solidification

•**Definition**: Solidification process where the outer layers solidify first, progressively forming a solid structure that moves inward.

•**Key Points**:

- Outer layers solidify as they come into contact with the cooler mold.
- The inner core remains molten longer, leading to directional heat flow.
- Helps minimize defects like shrinkage cavities.

•**Applications**: Used to control the cooling rate in casting processes, ensuring uniform quality in large castings.



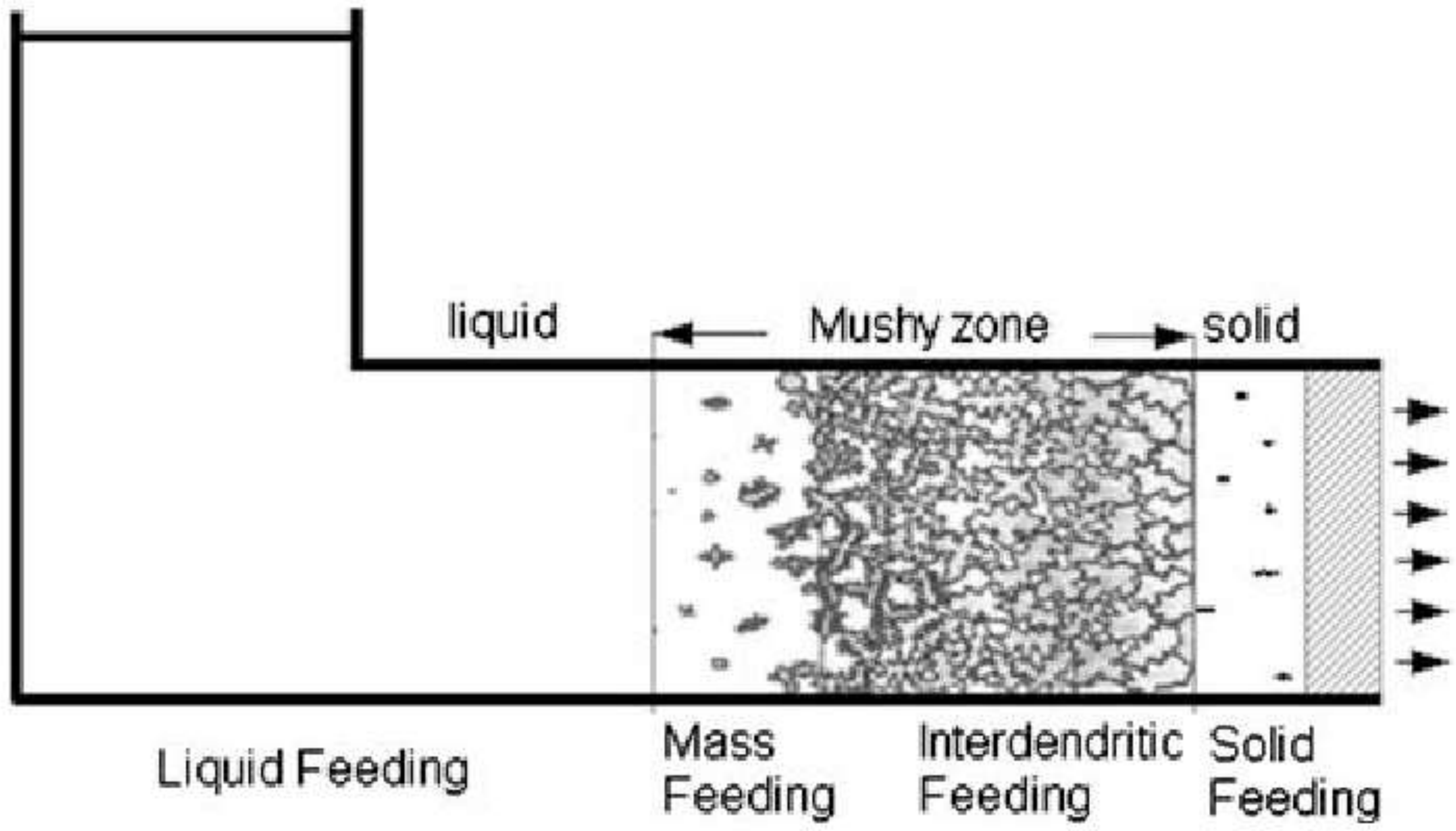
Centre in Feeding Resistance

•**Definition**: The resistance encountered by molten metal to flow into the center of a mold during solidification.

•**Cause**: As the outer solidifies, the center remains liquid and faces difficulty in receiving additional molten metal due to solidification of the surrounding areas.

•**Solutions**:

- Provide a sufficient feeder or reservoir of molten metal at the top of the casting to compensate for the shrinkage.
- Proper mold design (e.g., risers, gating system) to ensure adequate metal supply to the center.



Feeding Resistance and Solidification Rate

- **Relation**:
  - **Increased Resistance**: As the solidification rate increases (faster cooling), the metal at the center cools slower, which makes feeding harder. If the resistance is too high, voids or shrinkage cavities form in the center of the casting.
  - **Slower Solidification**: A slower solidification rate (due to lower cooling rates) allows the metal to feed more easily to the center, reducing the likelihood of shrinkage.

Controlling Feeding Resistance

- **Methods**:
  - **Feeder/Riser Design**: Using risers and feeders that provide molten metal to the center during solidification.
  - **Mold Design**: Strategic placement of chills or insulating materials to create desired cooling rates. This helps control the temperature gradient and reduces feeding resistance.
  - **Alloy Composition**: Choosing metals with slower solidification rates to reduce feeding issues.

Rate of Solidification	Feeding Resistance	Effect on Casting
Fast	High	Increased resistance to feeding molten metal to the center, leading to potential shrinkage cavities or voids in the center.
Medium	Moderate	Moderate resistance; may still lead to some feeding issues in large castings, but manageable with appropriate riser design.
Slow	Low	Reduced resistance, allowing molten metal to feed easily to the center, minimizing shrinkage and improving casting integrity.

Electrical analog of solidification problems

The **electrical analog of solidification problems** is often used to simplify and visualize heat transfer and solidification phenomena in casting processes. It models the solidification process as an electrical circuit, where various parameters (temperature, heat flow, and resistance) are analogous to electrical components (voltage, current, and resistance).

Solidification Phenomenon	Electrical Analog
Heat Transfer	Current Flow
Temperature Gradient	Voltage Gradient
Thermal Resistance (Heat Transfer Resistance)	Electrical Resistance
Mold Material (Thermal Conductivity)	Conductor (Material's ability to conduct electricity)
Solidification Rate (Cooling)	Current Flow Rate (Heat Flow Rate)
Feeding Resistance (Center Feeding Resistance)	Resistive Loss (Opposition to current flow)
Shrinkage in Center	Voltage Drop (Loss due to resistance)

Explanation of the Analog:

1. **Heat Transfer = Current Flow**:
   1. Just like current flows through an electrical circuit, heat flows through the casting. The flow of heat from the molten metal to the cooler mold is analogous to the flow of electrical current in a conductor.
2. **Temperature Gradient = Voltage Gradient**:
   1. The temperature difference across the casting creates a gradient, similar to how a voltage gradient exists across an electrical circuit. Higher temperature gradients lead to faster solidification at the outer surfaces and slower at the center.
3. **Thermal Resistance = Electrical Resistance**:
   1. Just as electrical resistance limits the flow of current, thermal resistance limits the rate of heat flow from the molten metal to the mold. Materials with higher thermal resistance (poor conductors) slow down the solidification process.
4. **Mold Material = Electrical Conductor**:
   1. The mold material's ability to conduct heat is similar to how an electrical conductor affects the flow of current. The mold's thermal conductivity determines how efficiently heat is transferred from the molten metal.
5. **Solidification Rate = Current Flow Rate**:
   1. The rate at which molten metal solidifies is related to how quickly heat flows out of the system. This corresponds to how quickly electrical current flows through the circuit, affecting the overall process.
6. **Feeding Resistance = Resistive Loss**:
   1. Feeding resistance is the difficulty molten metal faces in moving toward the center of the mold during solidification. In the electrical circuit, resistive losses occur when the current encounters high resistance, limiting the flow. Similarly, when the center of the casting solidifies and shrinks, the molten metal faces more resistance to flow into the center.
7. **Shrinkage in Center = Voltage Drop**:
   1. Shrinkage in the center of the casting due to solidification can be compared to a voltage drop in an electrical circuit. The central voids or cavities that form in a casting represent areas where the "flow" of molten metal is obstructed, akin to areas of high electrical resistance in a circuit.

Visualizing the Electrical Analog

Think of a simple electrical circuit where:

•**Current** flows through a **resistor** (thermal resistance), creating a **voltage drop** (temperature gradient).

•The material's **conductivity** (thermal conductivity) affects the current's flow, just like the casting material affects the heat flow during solidification.

The combination of these elements helps explain solidification issues such as feeding resistance and shrinkage, making the complex process more understandable.

THANK YOU !