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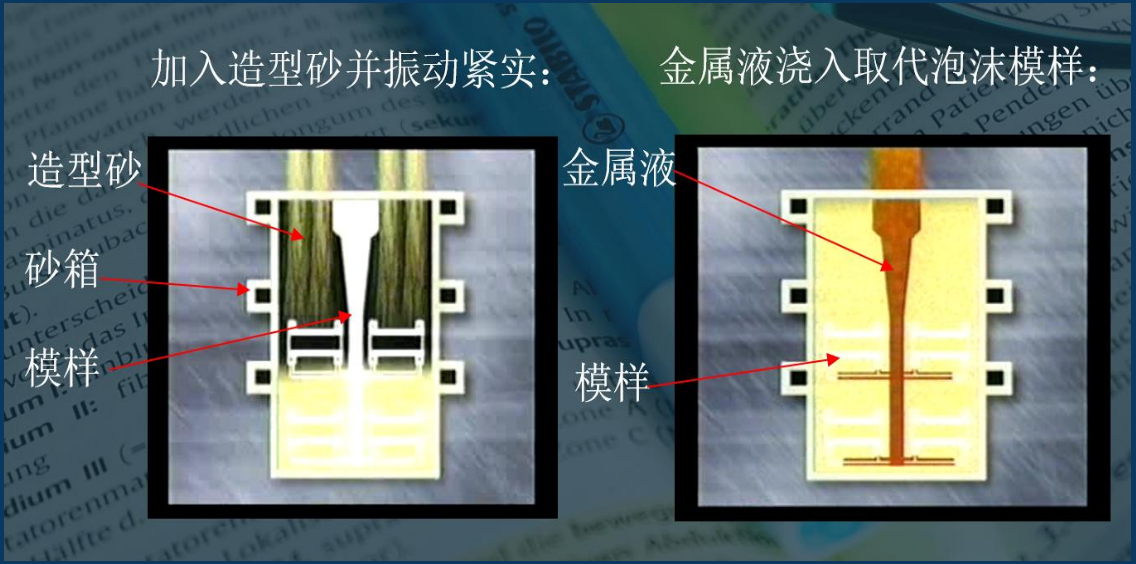
Lost Foam Casting

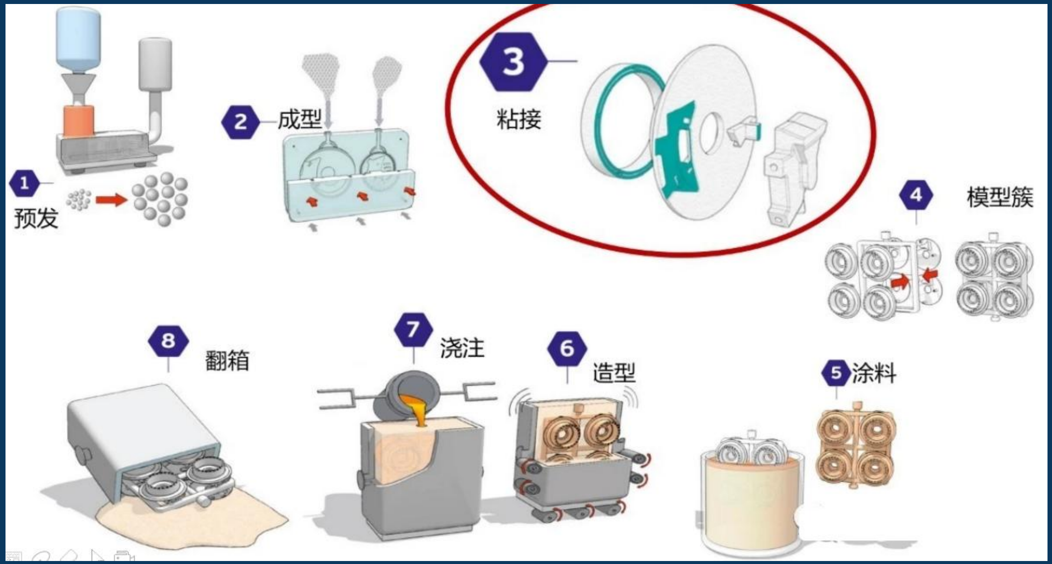
（Full Mould Casting）

Chapter 1: Introduction

Brief Introduction to Lost Foam Casting Process

Lost Foam Casting (LFC), also known as Full Mold Casting, is an innovative casting method. It involves assembling foam patterns that resemble the structure, dimensions, and shape of the final casting into a pattern cluster. After being coated with a refractory material and dried, the pattern is embedded in dry sand and compacted through vibration. During pouring under vacuum conditions, the foam pattern vaporizes, allowing the molten metal to occupy its position. After solidification and cooling, the final casting is formed.





1.1 Overview

The modern lost foam casting foam resin was invented and patented by American H.F. Shroyer in 1958.

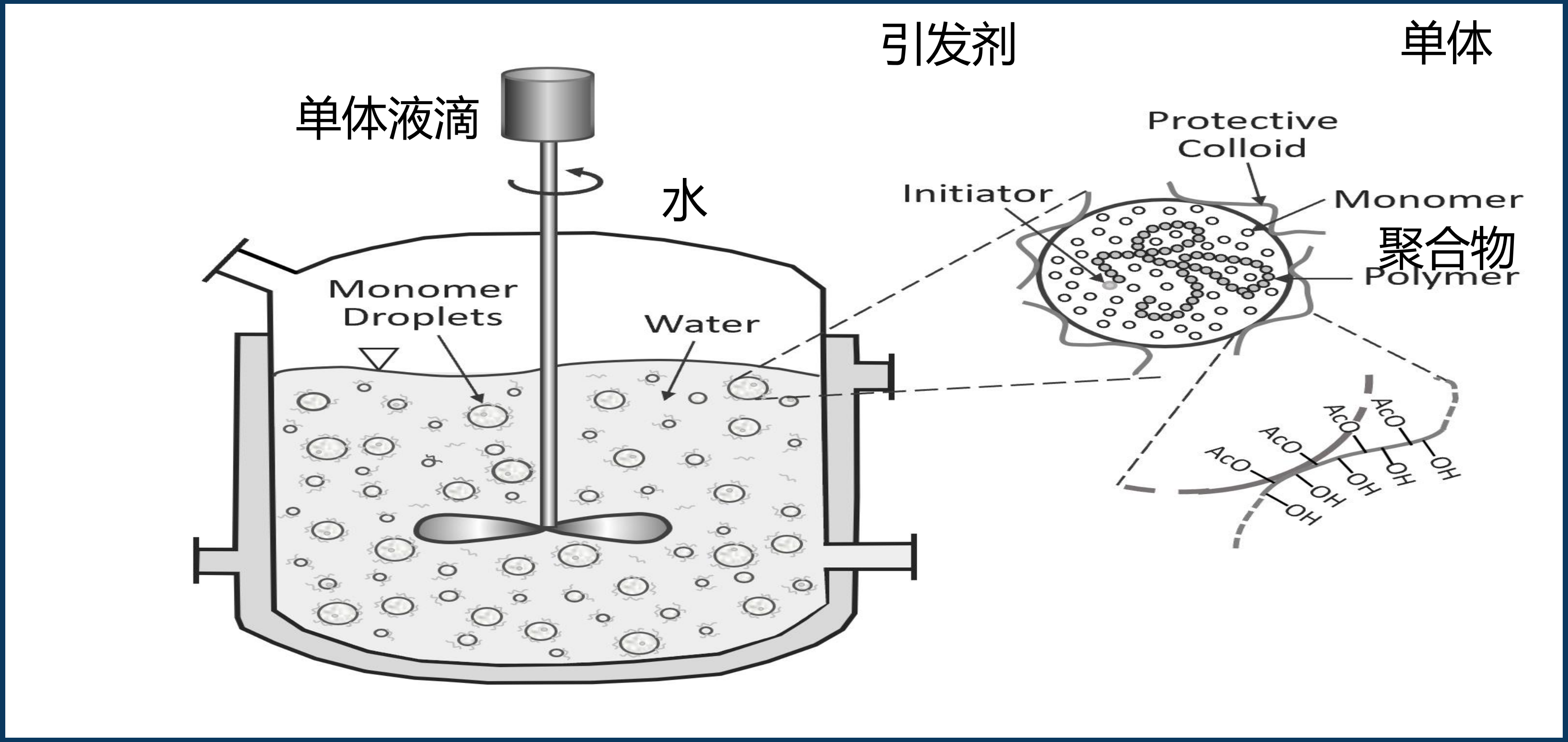
In 2002, Zhejiang Castchem New Materials Co., Ltd. successfully localized its production in China. The company developed STMMA (Expandable Copolymer Resin) to replace traditional EPS, making it the preferred material for lost foam casting of ductile iron parts. In 2010, the company introduced a derivative product, FD, specifically designed for lost foam casting of gray iron parts. In 2024, Zhejiang Castchem achieved domestic production of EPMMA (Expandable Polymethyl Methacrylate), which helps reduce defect rates in lost foam casting of steel products.

STMMA Raw Beads

Pre-expanded STMMA Beads

1.1 Overview

The production process of lost foam copolymer beads (STMMA) involves a highly complex polymerization reaction. Castchem employs a one-step suspension polymerization method, introducing a third monomer into the original copolymer monomer system. This approach ensures a stable and controlled exothermic reaction during polymerization, allowing the copolymer beads to grow gradually and achieving a well-regulated, lower molecular weight copolymer bead structure.



1.1 Overview

Classification of Suspension Polymerization:

- **Suspension Polymerization**
  - **Homogeneous Polymerization**
    - The polymer produced is soluble in the monomer.
    - Styrene, Methyl Methacrylate
  - **Heterogeneous Polymerization**
    - The polymer produced is insoluble in the monomer and precipitates
    - Vinyl Chloride, Trifluorochloroethylene, Tetrafluoroethylene

1.1 Overview

Characteristics of Suspension Polymerization:

Advantages:
- Simple process.
- Easy control of polymerization heat.
- Products are easy to separate, wash, and dry, resulting in high purity (compared to emulsion polymerization).

Disadvantages:
- Cannot be operated continuously.
- Compared to bulk polymerization, the product may still contain impurities such as dispersants.

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1.1 Overview

Granulation Mechanism:

Granulation Mechanism: From Droplet to Polymer Particle

Dispersing Agent → Liquid Dispersion → Stirring → Particle Characteristics.

Polymerization Mechanism: Free Radical Polymerization

Initiator → Polymerization Kinetics → Heat Transfer → Temperature Control → Molecular Characteristics.

1.1 Overview

Formation and Control of Suspension Particles

Industrial Treatment of Immiscible Liquids:

1. Stable Dispersion:
   - Emulsifier → Emulsion
   An emulsifier stabilizes the mixture of immiscible liquids, forming a stable emulsion where one liquid is dispersed in the other.

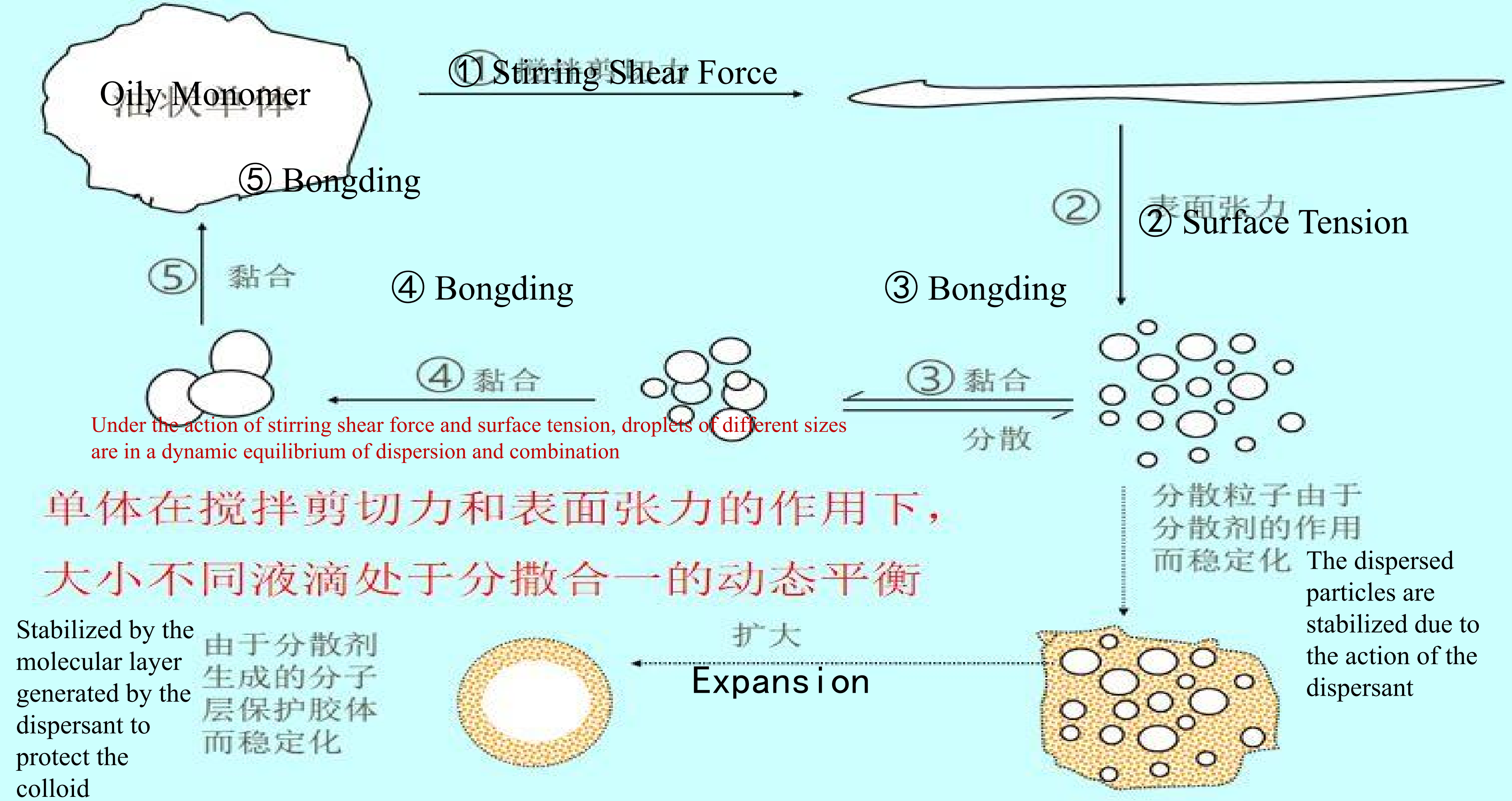
2. Unstable Dispersion:
   - Stirring Dispersion → Stirring Stops → Stratification
   If the dispersion is unstable, it may require stirring to remain dispersed, but once the stirring stops, the immiscible liquids will separate into distinct layers due to their inability to mix.

3. Turbulent Flow → Stable Dispersion:
   - Dispersing Agent and Mechanical Stirring → Suspension Polymerization
   In turbulent flow conditions, dispersing agents combined with mechanical stirring can create a stable dispersion, which can be used in suspension polymerization processes.

Winslow Mechanism Diagram (See next page)

1.1 Overview

Formation and Control of Suspension Particles



1.1 Overview

Phase Formation Process: Homogeneous

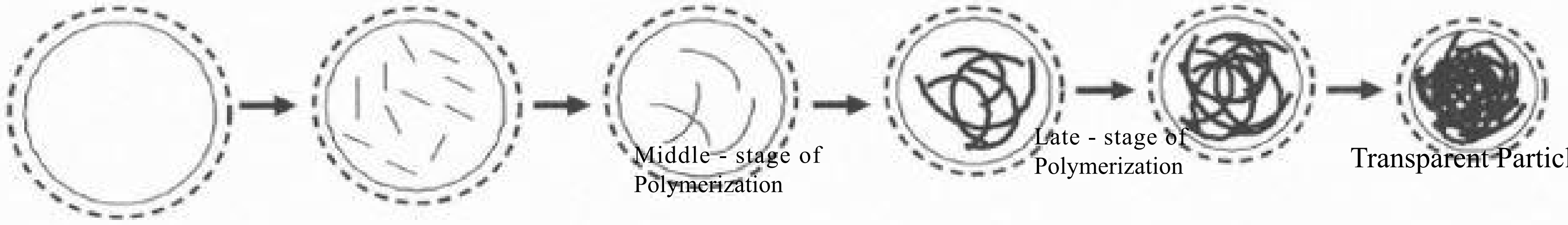


图 5-2 均相悬浮聚合的成粒过程
Figure 5 - 2 The Granulation Process of Homogeneous Suspension Polymerization

聚合过程中，单体转化率在20%——70%范围为粘稠液体状态，为结块危险阶段；

During the polymerization process, when the monomer conversion rate is in the range of 20% - 70%, it is in a viscous liquid state, which is a dangerous stage for agglomeration

加入分散剂，以防止聚合中期发粘液滴合并

Dispersant is added to prevent the sticky droplets from merging in the middle - stage of polymerization

1.1 Overview

Phase Formation Process: Homogeneous

Granulation Process 成粒过程	Conversion Rate 转化率	Particle Name 粒子名称	Particle Morphology 粒子形态	Particle Size 粒子尺寸
Initiation Stage 引发阶段	<1%	Short - chain Free Radicals		More than 10 monomer units in the chain
First Aggregation 第一次聚集	<1%	Micro - domain Structure		10~20nm
Second Aggregation 第二次聚集	1%~2%	Regional Structure		100~200nm
Chain Propagation 链增长	4%~10%	Primary Particles 初级粒子		200~400nm
Third Aggregation 第三次聚集	10%~90%	Secondary Particles 次级粒子		2~10μm
Fourth Aggregation 第四次聚集	10%~90%	Product Particles 产品颗粒		100~180μm

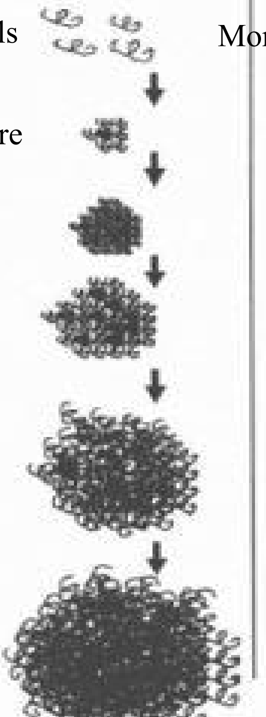


Figure 5 - 3 The Granulation Process of Heterogeneous Suspension Polymerization

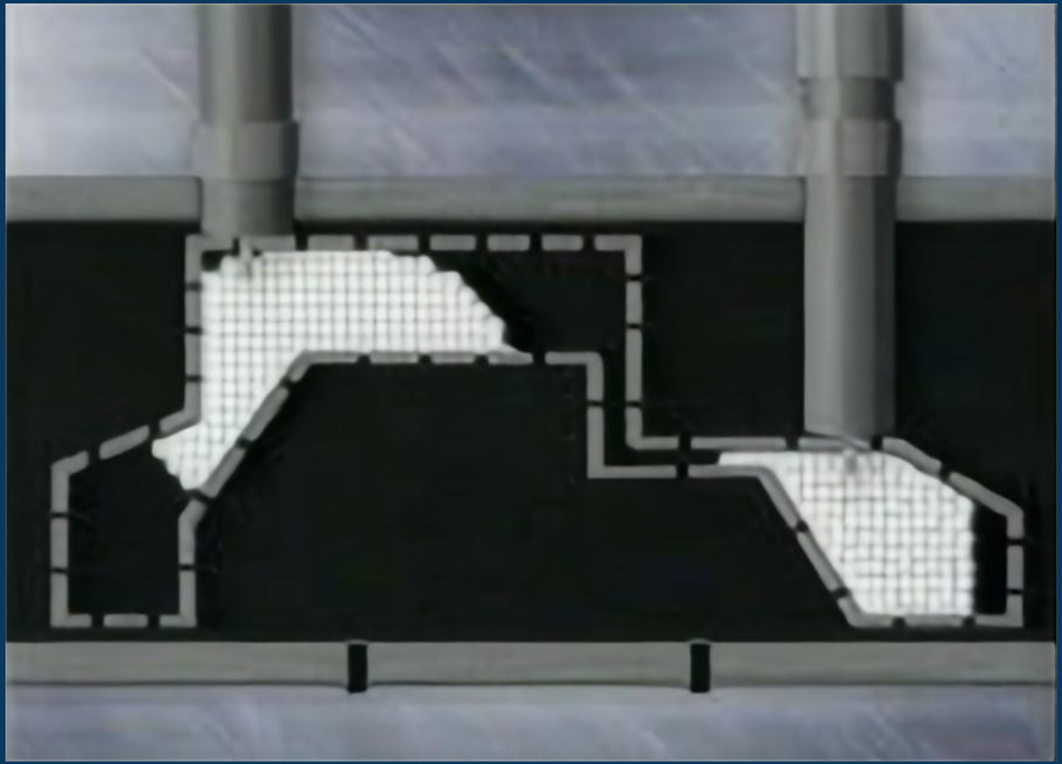
图 5-3 非均相悬浮聚合的成粒过程

Precipitation Polymerization inside the Droplets; The Polymerization Products Aggregate Multiple Times to Form the Final Particles

液滴内部的沉淀聚合；聚合产物多次聚集形成最终颗粒

1.1 Overview

The expand STMMA beads are filled into the mold, occupying the entire cavity. After steam heating and pressurization, the beads expand, and upon expansion, they bond together, forming a complete mold.

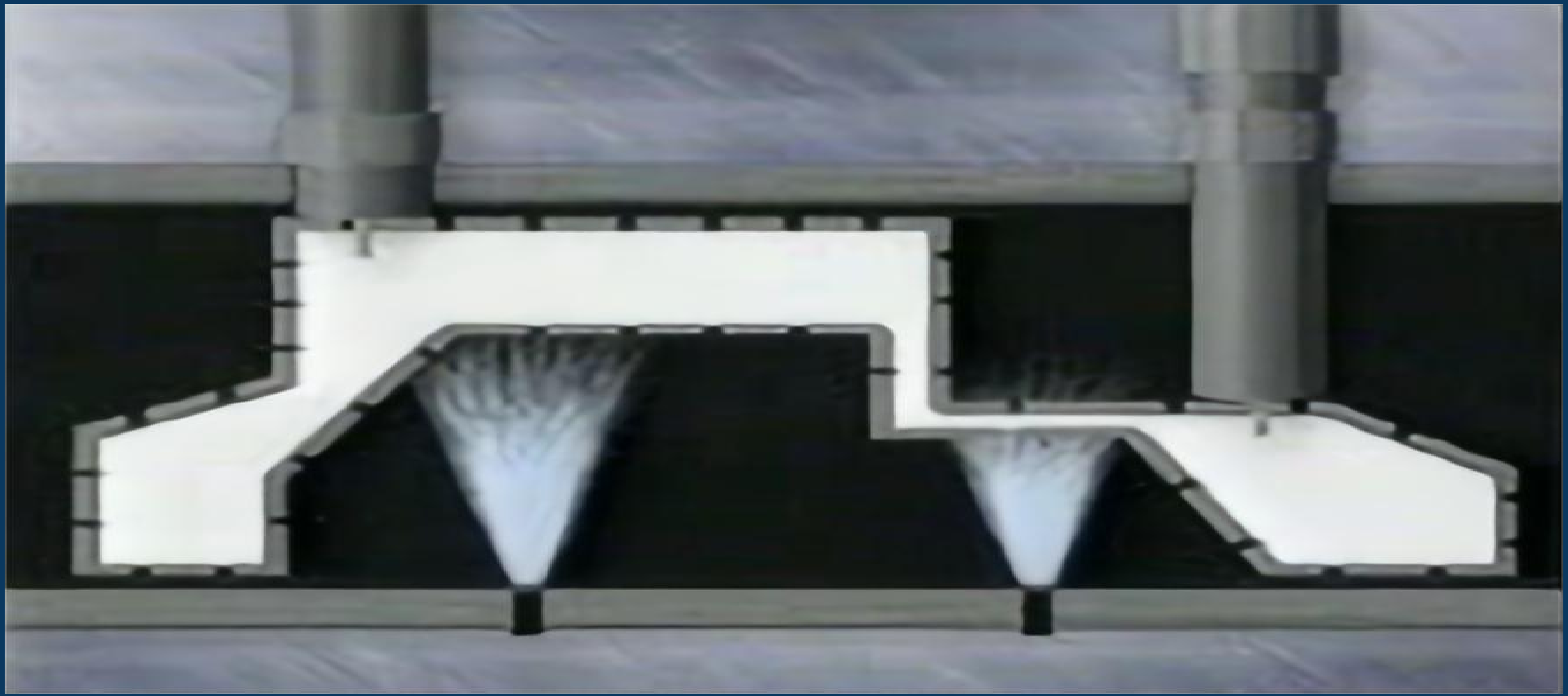


Foam Bead Filling Schematic Diagram

Schematic Diagram of Steam Heating Molding

1.1 Overview

The mold is cooled with cooling water, and the expansion of the model stops upon cooling. The model is then removed and placed in the model storage for curing. To reduce the curing time, the model storage should ideally be a warm room or a glass greenhouse with a temperature of 25-35° C. The storage environment should be warm yet well-ventilated.



Schematic Diagram of Foam Bead Model Cooling

1.1 Overview

After the model is fully cured, the next step is the lost foam casting coating process.
The main functions of the lost foam casting coating are:

To increase the strength of the foam plastic pattern and prevent it from being damaged or deformed during transportation or sand filling vibration.
During pouring, the coating layer serves as an important isolating medium between the liquid metal and the dry sand, preventing the molten metal from directly entering the dry sand.
The coating layer allows the thermal decomposition products of the foam plastic model (such as large amounts of gas or liquid) to smoothly escape outside the mold, preventing defects such as porosity or carbon black in the casting.

Lost Foam Water-Based Refractory Coating Dipping Site

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1.1 Overview

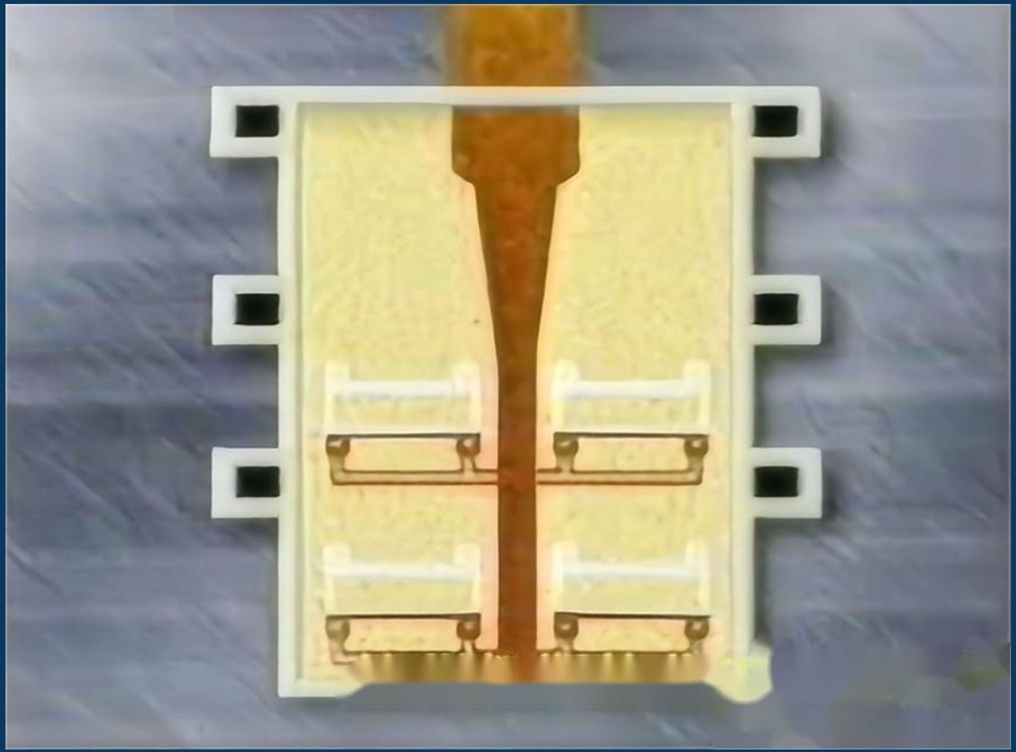
Lost foam coating must possess sufficient adhesion, wettability, leveling ability, thixotropy, suspension, permeability, and both room temperature and high-temperature strength.

Model without Coating

Model with Coating Applied

1.1 Overview

Before adding molten iron into the ladle, it is necessary to clean any detached impurities. The ladle should then be preheated to the desired temperature to prevent the formation of oxide scales on the molten iron. The distance from the molten iron area to the casting area should be as short as possible to prevent the molten iron from cooling too quickly. When pouring the molten iron, the pouring speed should be determined based on the size, material, and shape of the casting. However, one constant is that the pouring must be done at a uniform speed.

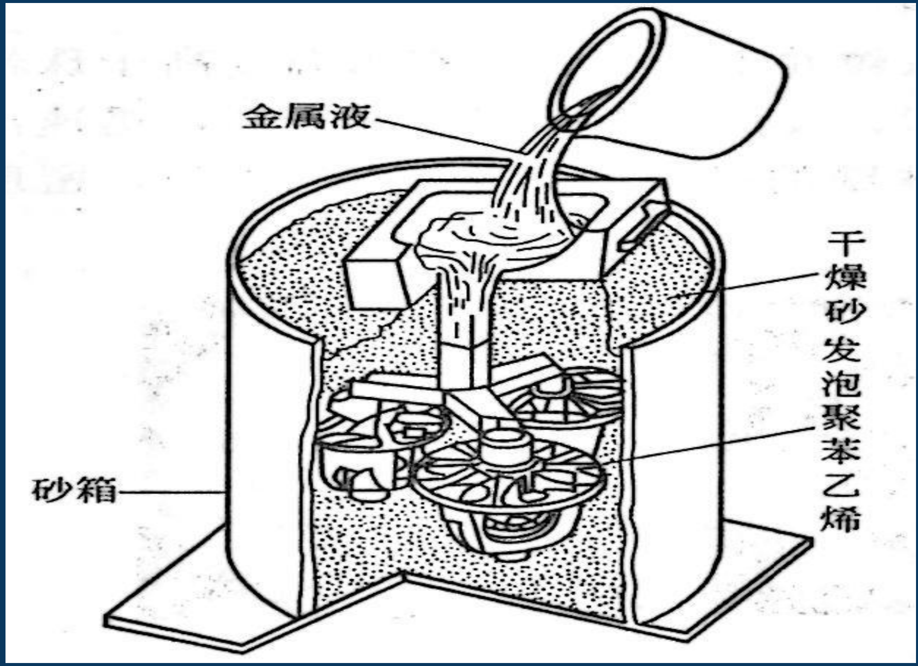


Schematic Diagram of Molten Iron Casting Forming

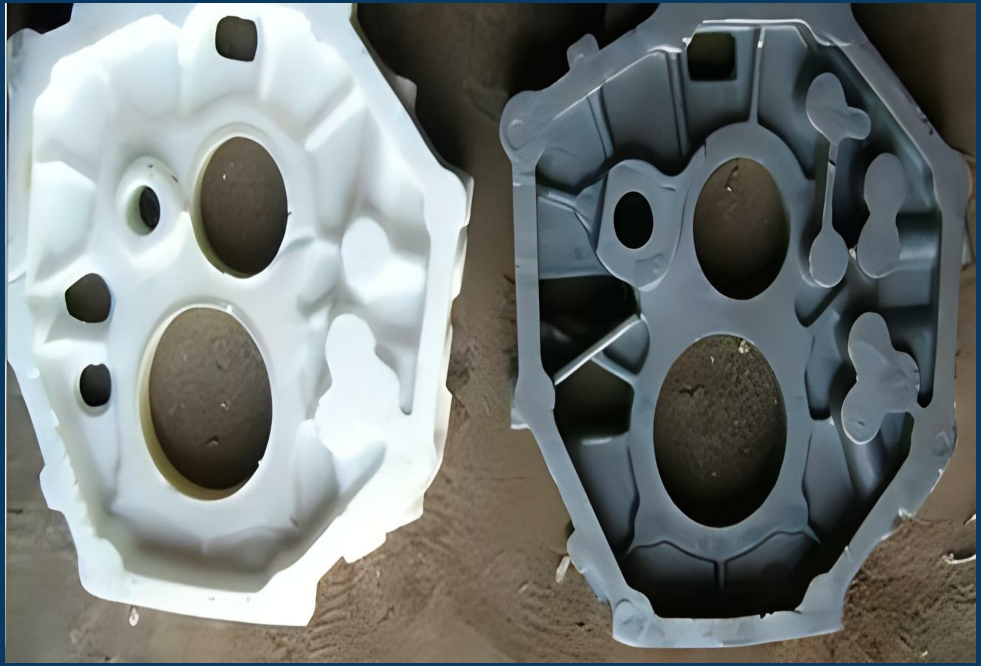
On-site Molten Iron Casting

1.1 Overview

The molten white mold is replaced by the metal liquid, which fills the entire mold cavity. The casting blank is then initially formed.



Schematic Diagram of Model Casting



The white mold transforms into the casting after pouring

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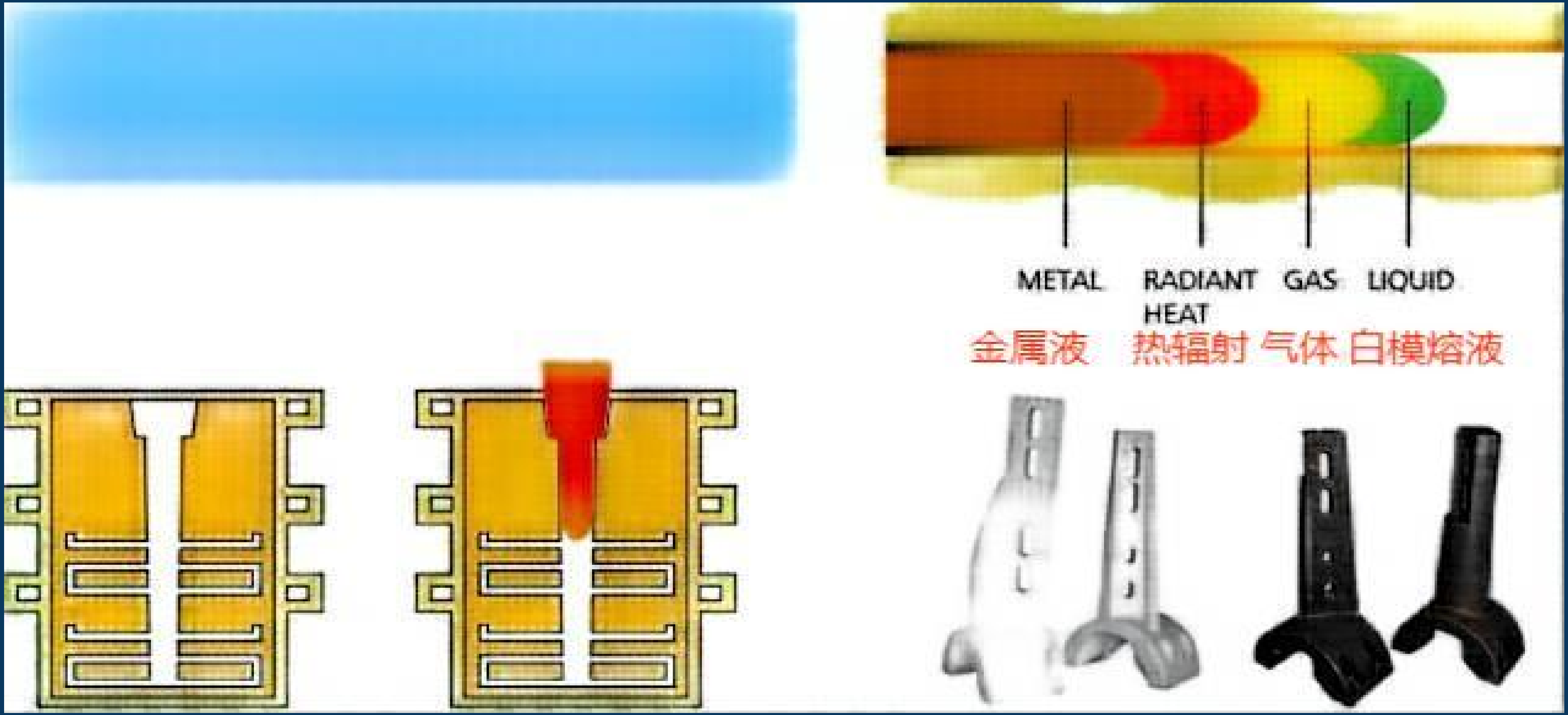
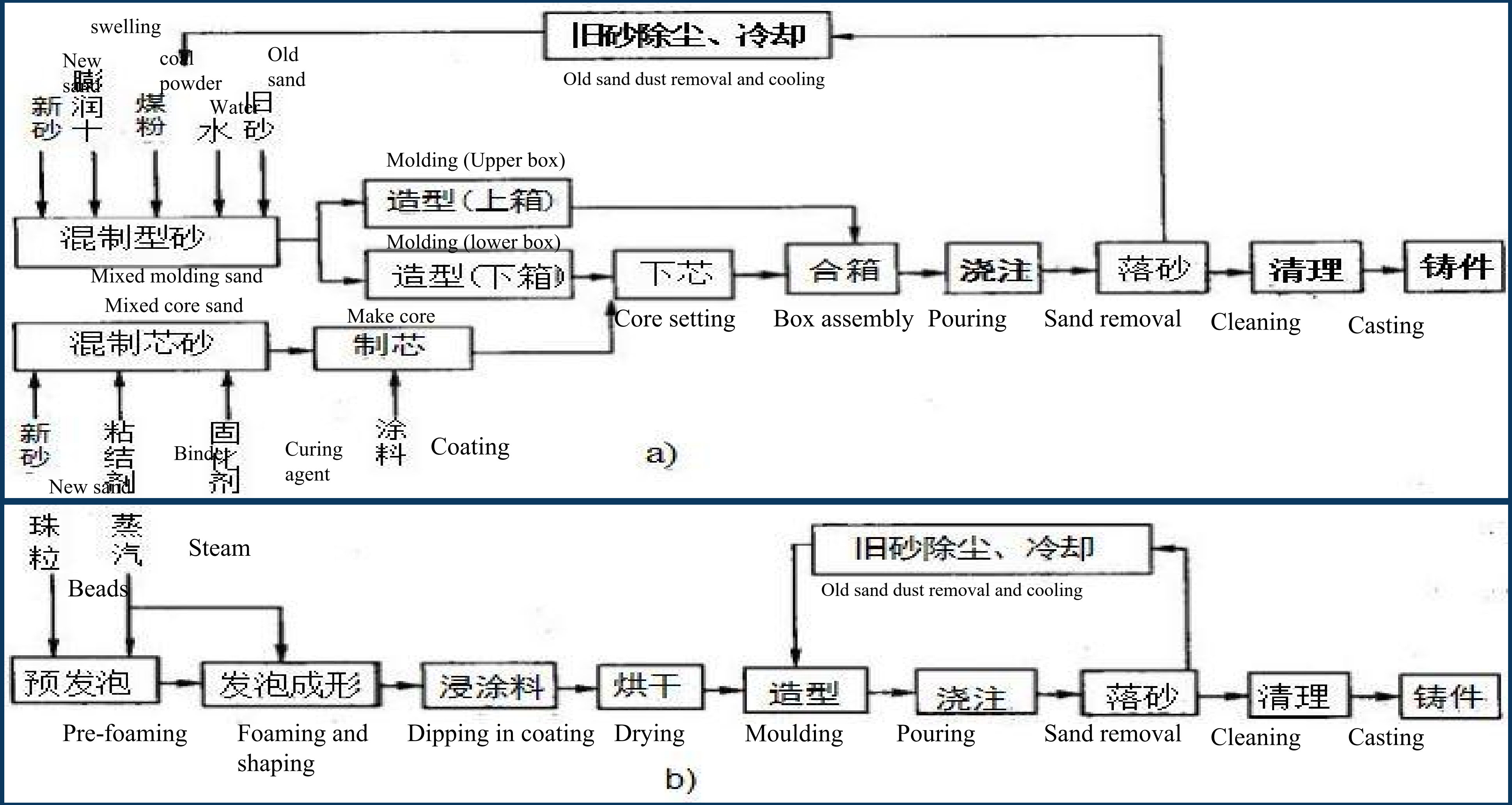
Schematic Diagram of Lost Foam Molten Iron Casting Process



Comparison of Lost Foam Casting and Clay Sand Casting Processes



a) Main Process Flow of Clay Sand Casting
b) Main Process Flow of Lost Foam Casting

1.2 Characteristics of Lost Foam Casting Process

Advantages of Lost Foam Casting

1. **High Casting Accuracy**:
Lost foam casting is a near-net-shape precision forming process that eliminates parting lines and sand cores, resulting in castings with minimal flash, burrs, and draft angles. This process reduces dimensional errors caused by core assembly and eliminates the need for core setting.

2. **Flexible Design**:
This process provides greater design freedom for casting structures. Components that were previously assembled from multiple parts can now be cast as a single unit by bonding several foam patterns together. Additionally, holes and cavities that previously required machining or sand cores can be directly cast, significantly reducing machining and core-making costs.

3. **Elimination of Traditional Sand Cores**:
The process uses dry sand filling for mold compaction, relying on the flowability of dry sand to form internal cavities and holes within the casting. For complex internal structures, the foam pattern can be divided into multiple sections, molded separately, and then bonded into a complete pattern. This prevents issues in traditional sand casting, such as uneven wall thickness due to inaccuracies in core size or positioning.

4. **Clean Production**:
Since no chemical binders are used in the sand, the environmental impact of foam decomposition at low temperatures is minimal. During pouring, organic emissions are low, short-lived, and concentrated in specific locations, making collection and treatment more manageable. The dry sand molding process significantly reduces casting shakeout and cleaning workload, while also minimizing workshop noise and dust. The reclamation rate of used sand exceeds 95%. Additionally, the lightweight foam patterns reduce labor intensity, and dust generated during sand filling can be efficiently collected and filtered, minimizing health risks to workers.

**Advantages of Lost Foam Casting (Continued)

5. **Reduced Investment and Production Costs**:
Compared to casting production lines with the same capacity, lost foam casting requires a lower initial investment. The molding sand is fully recyclable, with significantly lower consumption than clay sand. The sand reclamation system is simpler, and there are no costs associated with chemical binders. Additionally, the mold lifespan is longer and experiences less wear compared to traditional casting molds. The reduced casting wall thickness helps save material costs. Furthermore, labor requirements are reduced, work intensity is lowered, and both pattern production and casting can be automated, transforming the traditional casting industry's reputation for being labor-intensive, dirty, and exhausting.

Disadvantages of Lost Foam Casting

Foam Materials Cannot Be Reused:
Since the foam material burns and vaporizes during pouring, it cannot be recycled for reuse.
Challenges in Producing Large Castings:
In the early stages of lost foam casting, the production of large castings was difficult due to limitations in sand box size, the lack of large-scale pattern-making machines, multi-axis high-precision engraving machines, and specialized large-scale lost foam casting equipment. While these challenges have largely been overcome, the vacuum negative pressure process still carries a risk of mold collapse. Therefore, continuous improvements incorporating elements of both lost foam and solid mold casting processes are necessary.

Which Casting Processes Can Be Converted to Lost Foam Casting

I. Components of Different Casting Process Projects Based on Process Flow and Investment

1. **Lost Foam Casting Process:**
   - (1) **Melting Equipment** (including electric furnace, electrical control, transformer, and related power supply facilities)
   - (2) **Pouring Equipment** (including ladle, overhead crane, or pouring machine)
   - (3) **Lost Foam Casting Production Line** (comprising sand processing equipment, sandboxes, molding vibration table, and vacuum negative pressure system)
   - (4) **White Area and Yellow Area Equipment** and related supporting facilities
   - (5) **Patterns or Molds**

2. **Vacuum Sealed Molding (V-Process) Casting:**
   - (1) **Melting Equipment** (including electric furnace, electrical control, transformer, and related power supply facilities)
   - (2) **Pouring Equipment** (including ladle, overhead crane, or pouring machine)
   - (3) **V-Process Casting Production Line** (comprising sand processing equipment, sandboxes, molding vibration table, and vacuum negative pressure system)
   - (4) **Patterns or Molds**

Conversion Feasibility
Since both lost foam casting and V-process casting share similar equipment, such as vacuum negative pressure systems, sand handling systems, and molding vibration platforms, V-process casting can be relatively easily converted to lost foam casting by adding foam pattern-making capabilities and modifying the sand handling system accordingly.

Which Casting Processes Can Be Converted to Lost Foam Casting?

I. Components of Different Casting Process Projects Based on Process Flow and Investment

3. **Clay Sand, Resin Sand, Shell Mold, and Sodium Silicate Sand Casting Processes:**
   - (1) **Melting Equipment** (including electric furnace, electrical control system, transformer, and related power supply facilities)
   - (2) **Pouring Equipment** (including ladle, overhead crane, or pouring machine)
   - (3) **Corresponding Casting Production Line** (comprising sand processing equipment, sandboxes, molding, and core-making equipment)
   - (4) **Patterns or Sand Cores**

4. **Investment Casting (Lost Wax Process):**
   - (1) **Melting Equipment** (including electric furnace, electrical control system, transformer, and related power supply facilities)
   - (2) **Pouring Equipment** (including ladle, overhead crane, or other pouring devices)
   - (3) **Shell Mold Production Line**
   - (4) **Patterns or Molds**

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Equipment Usability When Converting Different Casting Processes to Lost Foam Casting

<table>
<tr><th></th><th>Non-Usable Equipment</th><th colspan="2">Usable Equipment</th></tr>
<tr><td>V-Process Casting</td><td>Sand boxes</td><td>Sand handling equipment, vacuum negative pressure system</td><td rowspan="6">For all casting projects, melting equipment and pouring equipment are universally applicable.</td></tr>
<tr><td>Clay Sand</td><td>Casting production line, patterns or molds, sand boxes</td><td></td></tr>
<tr><td>Resin Sand</td><td>Casting production line, patterns or molds, sand boxe</td><td></td></tr>
<tr><td>Shell Mold Sand</td><td>Patterns or molds, sand boxes</td><td>Semi-automatic and automatic production lines (need modification)</td></tr>
<tr><td>Water Glass Sand</td><td>Casting production line, patterns or molds, sand boxes</td><td></td></tr>
<tr><td>Investment Casting</td><td>Shell production line, patterns or molds, sand boxes</td><td></td></tr>
</table>

Issues to Consider When Converting to Lost Foam Casting Process

Comprehensive Analysis:

Investment in Lost Foam Casting: Compared to other casting processes, the investment for lost foam casting is lower for the same production capacity. However, due to the need for workers to produce and bond foam patterns in the foam pattern workshop, and workers to prepare coatings and dip the patterns in the coating workshop, the labor demand is not lower than that of other processes.

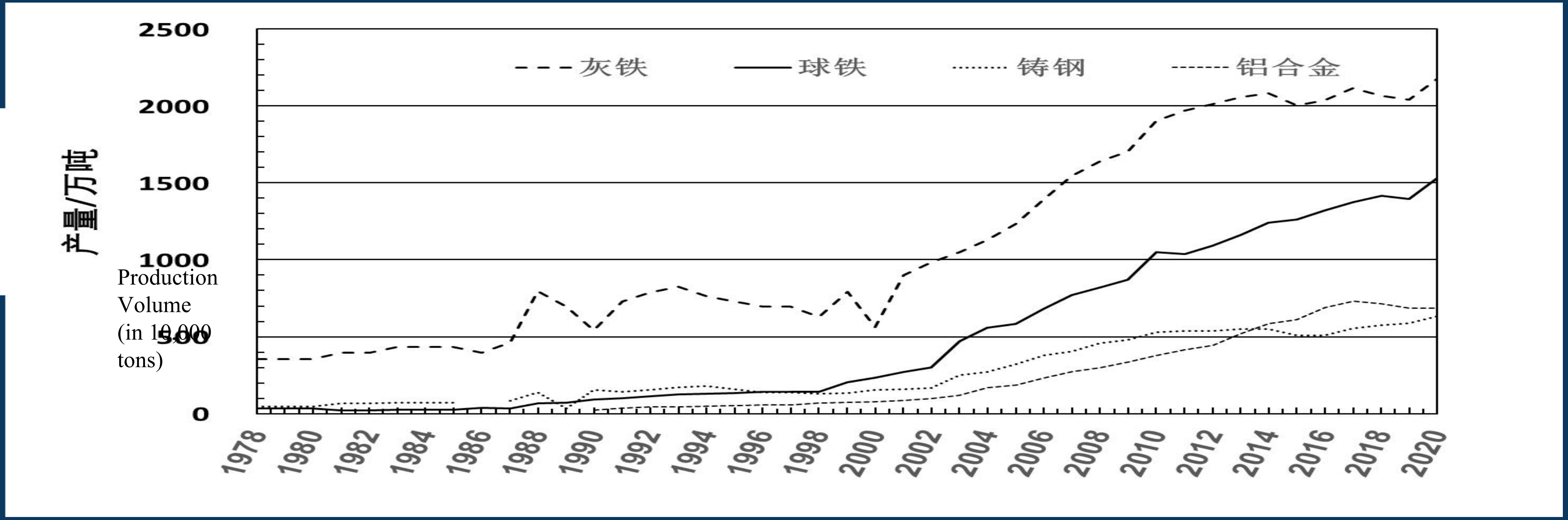
Significant Investment Modules: Apart from the factory building, the molds, pre-foaming equipment, curing ovens, and related facilities for lost foam casting can account for 30-50% of the total investment in a lost foam casting project, making it a significant investment module.

V-Process Casting: The melting, pouring, vacuum negative pressure system, and sand handling system in V-process casting can be shared with the lost foam casting process, making it the easiest casting process to transition into lost foam casting.

1.3 Development Status of Lost Foam Casting Technology at Home and Abroad

The following chart shows the global casting production volume. Theoretically, castings made from these various materials can all be produced using the lost foam casting technology.

The market potential for lost foam casting is enormous. However, many casting companies have not adopted this technology yet. The main reasons are that the global promotion of lost foam casting technology has not been ideal, and many countries do not even have a dedicated lost foam casting association. As the world's largest producer of lost foam castings, Chinese companies should intensify their international expansion efforts. They should better promote China’s excellent lost foam casting materials, equipment, and experience to the global market, aiming to grow the lost foam casting industry worldwide.



Reasons Why China’s Lost Foam Casting is Leading and Thriving Abroad

The introduction of lost foam technology to China coincided with the mid-stage of the country’s reform and opening up, when public sector reforms were beginning to show results. Many entrepreneurs who had gained wealth were eager to experience the benefits of technological innovation. As a new industry, many bosses were willing to try lost foam casting. Compared to traditional sand casting, lost foam casting offers advantages such as lower investment scale, smaller plant area requirements, and lower labor costs, which can be summarized as "low investment, quick results." However, there is a common saying in the lost foam industry: "Easy to learn, but hard to succeed." Therefore, many of the first entrepreneurs who adopted lost foam technology faced numerous challenges and paid a high price for their mistakes.

As one of the few countries with a complete industrial chain, China enjoys unique advantages in developing any industry, which is why lost foam casting has developed so rapidly in the country.

China’s lost foam material companies and lost foam equipment companies are interdependent. Without good equipment, high-quality materials alone cannot produce successful lost foam castings, and vice versa. Therefore, what we need to do is unite and expand together. The development of China’s domestic lost foam industry has reached a bottleneck, making it difficult to break through. However, the overseas market potential is vast.

We must first focus on making high-quality products and take pride in them. Lost foam casting is a challenging process, and if our products are subpar, how can we serve foreign clients or promote overseas markets?

The ecosystem of China’s domestic lost foam industry is also important. If entrepreneurs focus solely on cutting costs by offering low prices without considering quality, it will ultimately hinder the healthy, orderly, and sustainable development of the industry in China.

1.4 Prospects of Lost Foam Casting in China

Lost foam casting technology aligns with the overall trends in casting technology development in the new century and holds broad application prospects. For China to transition from a manufacturing giant to a manufacturing powerhouse, it must vigorously develop more near-net-shape, precision-cast products. Casting technology must meet the broader goals of environmental protection and sustainable development, achieving clean production. At the same time, it must adapt to increasingly personalized market demands, with greater freedom in product structural design. Lost foam casting can meet the needs of the market and users in these areas, offering significant development potential. By effectively leveraging its features and advantages, the future is very promising.

Currently, China’s lost foam casting technology is still in a phase of technological innovation and requires a process of technical accumulation. Only through hard work, solving problem after problem, and continuous exploration, research, and practice will the technology gradually mature.

The greatest difference between lost foam casting and traditional casting methods is that, during pouring, the cavity is not empty. High-temperature metal undergoes complex physical and chemical reactions with the foam plastic pattern, and the decomposition products of the foam plastic pattern at high temperatures lead to many defects in lost foam casting. Many factories in China currently use foam plastic, typically used for packaging materials, for casting production, which results in significant issues such as carbon black and porosity.

While China is a major producer of lost foam castings, it still has a long way to go before becoming a leading powerhouse in lost foam production. Issues related to mold design, manufacturing, foam molding processes, coatings, key equipment in both the white and black zones, and resolving the unique defects of various alloys must be addressed and solved step by step. This will improve the overall technical level, especially in producing complex, high-precision castings. However, with adequate preparation and determination, the future development of this new technology in China is equally bright。

1.4 Prospects of Lost Foam Casting in China

In the development of lost foam casting technology in China, it is crucial to address the following key issues:

Product Suitability: Lost foam casting is an advanced technology but not a universal solution. It has a certain scope of application. Before deciding whether a casting is suitable for the lost foam casting method, it is essential to carefully compare various processes and alternatives. It is unwise to rush into building a production line and conducting experiments without proper research. This approach can often lead to substantial investments that do not yield timely returns. Some castings are simply not suitable for lost foam casting, and traditional sand casting or other casting methods may be more technically appropriate or economically beneficial. Therefore, a thorough feasibility study and process validation during the project's early stages are necessary.

Complex and Precise Castings: Lost foam casting technology should be applied to produce more complex and precise medium- and high-difficulty castings, such as intricate box-shaped parts, cylinder heads, and cylinder blocks. This will allow the full advantages and economic benefits of the casting process to be realized.

Stable and Dimensionally Consistent Foam Particles: It is necessary to develop dimensionally stable and non-deforming foam particles, establish the best foam molding process standards, and understand the dimensional variation patterns between the foam mold, foam plastic, pattern, and casting. This will provide reliable data for designing complex molds. Furthermore, advanced and practical CAD/CAM/CAE systems for molds should be created, and high-precision, high-efficiency molding machines and bonding machines should be developed to enable the series production of these machines.

Higher Technical Requirements: Lost foam casting technology requires higher technical standards than traditional sand casting. There are still many unexplored and researchable topics in the "white zone," where foam plastic patterns are produced, as well as in the "black zone," which involves shaping, pouring, and cleaning processes. These areas require further study to address existing challenges and improve overall performance.