This is a professional technical book about lost foam casting technology, with a focus on introducing lost foam casting. The manufacturing process of the pattern material and white area.

In order to facilitate customers to further understand and master the professional knowledge of lost foam casting, and to solve the problem of lost foam casting. For practical issues in casting, we have attached our experienced technical team members and contact information in the appendix. Below, welcome everyone to inquire, and if necessary, we can also provide on-site service.

Technical service

Technical Service Hotline: 0571-89021299 4008910190

Pearl Quality Service Line:
Quality director: Dai Dongli 137 5087 4188

White area technical service hotline:
Technical Manager: Tang Shuming139 6808 3379
Deputy Manager of Technical Department: Yao Kai158 8881 3203

Black Zone Process Technology Special Line:
Tian Gong (cast steel parts): 138 6383 7156
Qi Gong (cast iron parts): 176 3597 3099

Dai Dongli Tang Shuming Yao Kai

Scan QR code to clarify doubts and solve troubles
Your suggestions can help us do better!

凯斯特
CASTCHEM
股票代码:873584

Lost Foam Casting (LFC)

Application of STMMA Copolymer Resin

This is a professional technical book about lost foam casting technology, with a focus on introducing lost foam casting. The manufacturing process of the pattern material and white area.

In order to facilitate customers to further understand and master the professional knowledge of lost foam casting, and to solve the problem of lost foam casting. For practical issues in casting, we have attached our experienced technical team members and contact information in the appendix. Below, welcome everyone to inquire, and if necessary, we can also provide on-site service.

Technical service

Technical Service Hotline: 0571-89021299 4008910190

Pearl Quality Service Line:
Quality director: Dai Dongli 137 5087 4188

White area technical service hotline:
Technical Manager: Tang Shuming139 6808 3379
Deputy Manager of Technical Department: Yao Kai158 8881 3203

Black Zone Process Technology Special Line:
Tian Gong (cast steel parts): 138 6383 7156
Qi Gong (cast iron parts): 176 3597 3099

Dai Dongli Tang Shuming Yao Kai

Scan QR code to clarify doubts and solve troubles
Your suggestions can help us do better!

凯斯特
CASTCHEM
股票代码:873584

Lost Foam Casting (LFC)

Application of STMMA Copolymer Resin

Technical service

Technical Service Hotline: 0571-89021299 4008910190

Pearl Quality Service Line:
Quality director: Dai Dongli 137 5087 4188

White area technical service hotline:
Technical Manager: Tang Shuming139 6808 3379
Deputy Manager of Technical Department: Yao Kai158 8881 3203

Black Zone Process Technology Special Line:
Tian Gong (cast steel parts): 138 6383 7156
Qi Gong (cast iron parts): 176 3597 3099

Scan QR code to clarify doubts and solve troubles
Your suggestions can help us do better!

Dai Dongli Tang Shuming Yao Kai

凯斯特
CASTCHEM
股票代码:873584

LOST FOAM CASTING (LFC)

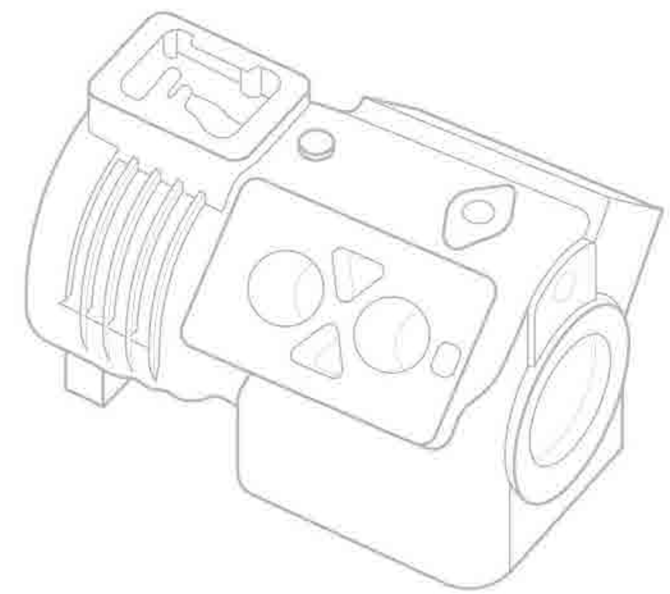
Application of STMMA Copolymer Resin

Contents

Contents

Chapter 1

Lost Foam Pattern Material



I. Brief Description of Lost Foam Casting Process

Lost foam casting process is a new process with almost no margin and for precise forming. This process does not require mold taking, and has no parting face or sand core, so the castings have no flash, burr and draft angle, thus reducing the size error caused by core assembly. Sand for lost foam casting does not contain any chemical binder, and is reusable. Owing to these above advantages, lost foam casting process has developed rapidly in China in recent years.

In the lost foam casting process, foam pattern is a unique pattern for lost foam casting. Foam pattern casting is a unique process of lost foam casting, but a series of chemical and physical reactions bring more uncertainties to the whole casting process. Therefore, the quality of the foam pattern directly affects the quality of the final castings, and the two important factors related to the quality of the foam pattern are the selection of foam pattern material and the control of pattern making process.

Patterns are indispensable consumables in lost foam casting process, and a pattern is consumed for each casting produced; the pattern not only gives the shape and size of lost foam casting, but also takes part in the physical and chemical reactions during casting. Therefore, the pattern affects not only the size and accuracy of the castings, but also the inherent quality of the castings; in the whole lost foam casting process, the pattern plays a decisive role; therefore, the pattern is the key to the success of lost foam casting.

With the development of lost foam casting, customers have higher requirements for the quality of the castings. As a lost foam casting company, improving the product qualification rate and quality and reducing production costs are still something we need to do. "Inferior products in white area have no difference with inferior products in black area", which is a fact known to all lost foam manufacturers around the world, and the lost foam pattern material is the most fundamental factor that restricts the healthy development of lost foam casting.

II. Analysis on Pattern Materials Used by Domestic and Foreign Lost Foam Casting Companies

High-quality pattern materials are the prerequisite for producing high-quality patterns. According to the use of pattern materials around the world, the foam bead materials suitable for lost foam casting process are currently divided into two categories:

One is expandable polystyrene (EPS), which is a polystyrene product with foaming agent added, and is colorless and transparent beads. Its common foaming agent is low-boiling point pentane. Representative products for lost foam casting: EPS for lost foam casting (T170, T180, T175A, T185F) produced by Styrochem Chemicals. Among them, T175A and T185F contain bromide and are suitable for aluminum alloy castings in lost foam casting; T170 and T180 are suitable for gray cast iron castings in lost foam casting. In future, we will be committed to R&D and production of foam beads for aluminum lost foam casting.

As we all know, China currently has no EPS beads for lost foam casting. Domestic lost foam casting companies are all using EPS for packaging or construction. The sources of these EPS beads are diverse, and sometimes raw materials of different properties are mixed together, resulting in numerous defects in our castings and higher production costs.

The other is expandable polymethyl methacrylate and styrene copolymer resin (STMMA), which is a copolymer in which methyl methacrylate is polymerized with styrene in a certain proportion (best ratio: 70:30 as currently recognized). It is milky white opaque beads, and its foaming agent is low-boiling point pentane. These foam beads are also the foam pattern material currently used by most lost foam casting companies around the world. Representative manufacturers of such foam beads: Japan's JSP (CL300-CL600 beads); Zhejiang Castchem New Material Co., Ltd. (STMMA copolymers, including STMMA and STMMA-FD expandable copolymer resins). Among them, STMMA beads are not only used for castings made of gray cast iron and plain carbon steel, but are also particularly suitable for castings made of ductile iron, mild steel, alloy steel, copper alloy and stainless steel. STMMA-FD beads are mainly used to replace EPS beads and are used in producing lost foam castings made of medium and low-end materials such as gray cast iron, plain carbon steel and some ductile iron.

III. Requirements for Foam Beads in Lost Foam Casting Process

Lost foam casting is a method of producing castings by replacing traditional molds (such as wood molds and metal molds) with foam patterns. It is different from other casting processes, so the factors that affect the quality of castings are also different. Foam patterns are indispensable consumables in lost foam casting, and a foam pattern is consumed for each casting produced. Therefore, the foam pattern is the key to the success of lost foam casting. High-quality castings cannot be separated from high-quality foam patterns.

The foam pattern not only gives the shape and size of the lost foam casting, but also takes part in the physical and chemical reactions during casting. Therefore, the foam pattern affects not only the size and accuracy of the castings, but also the inherent quality of the castings; regarding how to truly produce a high-quality casting, the foam pattern material for lost foam casting is crucial.

There is a wide variety of foam pattern materials, but the pattern materials for lost foam casting should meet the following requirements:

(1) The carbon content of foam beads should be low;

(2) The gasification temperature and gas evolution rate of the lost foam pattern should be low;

(3) The patterns are decomposed and gasified quickly and completely, and produce few residues;

(4) Foam beads have a long shelf life and the beads are moderately priced;

(5) Foam patterns feature low density, good strength and surface rigidity;

(6) Beads have a complete range of varieties and specifications, and can meet the patternmaking needs of the castings of different materials and structures.

IV. Selection of Foam Beads for Lost Foam Casting

1. Impact of lost foam pattern products on casting quality

Foam pattern is a unique pattern for lost foam casting. Foam pattern casting is a unique process of lost foam casting, but a series of chemical and physical reactions brings more uncertainties to the casting process. Therefore, the corresponding measures should be taken to eliminate potential quality hazards.

Foam pattern casting is in parallel with the casting process, and the products formed are carbides, carbon, carbon dioxide and water. Carbon dioxide and water are gases. As long as they are discharged in time, they will not have any adverse effect on the quality of the castings. Part of the carbon in the form of graphite is absorbed by the coating or discharged; part of it is absorbed by liquid metal, producing a recarburization effect. Carbon that has not been absorbed or discharged will not have any adverse effect on the internal and external quality if dispersed on the surface of the castings. If concentrated in the presence of liquid metal, macroscopic defects, namely carbon defects, will happen.

Carbides are large particulate matters that are not absorbed or discharged and must appear in the form of carbon defects of varying shapes and sizes. Carbon defects are one of the most difficult defects to overcome in lost foam casting, which greatly restricts the expansion of product categories. Under the same process conditions, improving the gasification effect of foam pattern decomposition and reducing solid residues are the most effective ways to reduce and eliminate carbon defects. Therefore, selecting qualified beads and preparing qualified foam patterns are the prerequisites for successful lost foam casting.

2. Introduction to common beads in lost foam casting

(1) Expandable polystyrene (EPS) beads are made by polymerizing styrene and then immersing it in a foaming agent.

Molecular formula: (C8H8)n

Structural formula (see Figure 1.1):

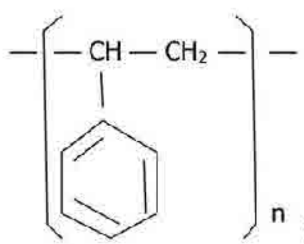


Figure 1.1 Molecular structure of EPS

Each ethylene molecule combines with 1 benzene molecule, a benzene ring, to form 1 styrene molecule. The benzene ring is not easy to add and oxidize, and the carbon ring is extremely stable.

Each styrene molecule has 8 carbons and 8 hydrogens, and contains 92% carbon. For foam beads used in lost foam casting, the ideal decomposition products are carbon dioxide and water, that is, gasification. The degree of gasification is the measure for testing the decomposition level of beads. In polystyrene, benzene rings stabilized by carbon rings occupy a high proportion, so the EPS beads are gasified poorly. According to the law of conservation of energy, the decomposition of excessive solid residues may cause numerous carbon defects. If stable or flame-retardant ingredients are used during polymerization, more solid residues will be decomposed, which will pose great harm to the quality of the castings.

(2) STMMA copolymer resin

Styrene is polymerized with methyl methacrylate (PMMA) in different proportions, and then immersed in a foaming agent during polymerization to make an expandable copolymer resin.

Molecular formula: $[(C_5H_8O_2)\,x\,(C_8H_8)y]$

Structural formula (see Figure 1.2):

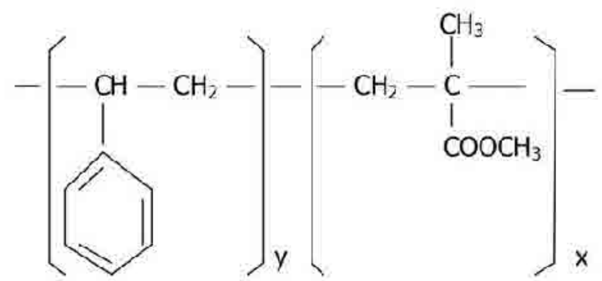


Figure 1.2 Molecular structure of STMMA

Methyl methacrylate has a molecular chain structure that is easy to decompose, and has no benzene ring, but very strong gasification capacity. After styrene is copolymerized with methyl methacrylate, the proportion of benzene rings in the copolymer molecular chain decreases. Besides, the rapid decomposition of methyl methacrylate can catalyze the decomposition of benzene rings. Therefore, the STMMA copolymer resin is more fully decomposed and highly gasified, and produces fewer solid residues during decomposition, thereby reducing carbon defects caused by casting.

The greater the amount of methyl methacrylate copolymerized, the more fully the foam pattern will be decomposed, and the higher the degree of gasification.

According to the copolymerized amount of methyl methacrylate (PMMA), casting-specific STMMA copolymer resins are divided into three series: STMMA-FD, STMMA and EPMMA.

A. STMMA-FD beads are a kind of resin in which methyl methacrylate is copolymerized with styrene in different proportions. The amount of methyl methacrylate involved in the polymerization of STMMA-FD is appropriate, and the beads contain 82% carbon. It can be more fully decomposed and highly gasified, with few solid residues, so it can be regarded as modified EPS.

Physical and chemical indexes of STMMA-FD are given in Table 1.1 (draft of machinery industry group standards for review):

Table 1.1 Physical and Chemical Indexes of STMMA-FD Expandable Copolymer Resin

Item	Index			
	Bead size, d, mm	Foaming ratio (120°C,10min)	Volatile matter, wt. %	Bulk density, g/mL
Special specifications of STMMA-FD	0.90⩽d<1.25			
STMMA-FD 1# (large size)	0.71⩽d<0.90			
STMMA-FD 1# (small size)	0.60⩽d<0.80	⩾40.0	⩾4.50	0.500~0.650
STMMA-FD2#	0.40⩽d<0.65			
STMMA-FD3#	0.35⩽d<0.45			
STMMA-FD4#	0.25⩽d<0.35			
Note: The weight ratio of beads within the bead size is greater than 90%				

B. STMMA copolymer resin is an expandable copolymer resin from suspension polymerization with methyl methacrylate, styrene, and low-boiling hydrocarbon foaming agents as the main raw materials, and peroxide as the initiator. The proportion of methyl methacrylate involved in the polymerization of STMMA is high, and the beads contain 63% carbon. It can be fully decomposed and highly gasified, with fewer solid residues.

Physical and chemical indexes of STMMA copolymer resin are given in Table 1.2 (JB/T 11846 standard for machinery industry):

Table 1.2

Item	Index			
	Bead size, d, mm	Foaming ratio (120°C,10min)	Volatile matter, wt. %	Bulk density, g/mL
STMMA-1#	0.85⩽d<0.90	⩾50.0	7.0~12.0	
STMMA-2#	0.65⩽d<0.85	⩾50.0	7.0~12.0	
STMMA-3A	0.50⩽d<0.65	⩾45.0	7.0~12.0	0.530~0.600
STMMA-3#	0.35⩽d<0.50	⩾45.0	7.0~12.0	
STMMA-4#	0.25⩽d<0.35	⩾40.0	7.0~12.0	

Note 1: The weight ratio of beads within the bead size is greater than 90%

Note 2: JB/T 11846~2014 standard for machinery industry has been revised and submitted for review. This table provides revised indexes. The "bead size" and "volatile matter" are different from 2014 standard.

3. Comparison of main indexes of common beads for lost foam casting

(1) Main properties of EPMMA, STMMA, FD and EPS (see Table 1.3):

Table 1.3 Comparison of Physical and Chemical Indexes of EPMMA, STMMA, FD and EPS

Item	Physical and chemical indexes			
	EPMMA	STMMA	FD	EPS
Bead size, mm	0.25~0.85	0.25~0.85	0.35~1.25	0.35~1.8
Foaming ratio, times (120°C,10min)	40~65	65~75	50~70	50~70
Volatile matter, % (150°C/1h)	10.50~11.50	9.00~10.00	6.50~7.50	4.50~6.50
Apparent density, g/mL	0.550~0.560	0.530~0.600	0.500~0.650	0.590~0.600
Carbon content, %	45	63	82	92
Gas evolution rate (1000°C), mL/g	900	800	700	600

(2) Comparison of pre-foaming parameters of beads (see Table 1.4):

Table 1.4 Comparison of Pre-foaming Parameters of Beads

Item	EPMMA	STMMA	FD	EPS
Pre-foaming temperature (°C)	95~105	95~105	90~95	90~95
Pre-foaming pressure (Mpa)	0.03~0.05	0.03~0.05	Normal pressure	Normal pressure
Pre-foaming time (s)	40~60	40~60	15~25	15~25
Curing time (h)	24~48	24~48	8~24	8~24

4. Selection of beads for lost foam casting

(1) The carbon equivalent of gray cast iron is generally 3.7%~4.1%, and the liquidus temperature is relatively low, about 1,200°C~1,230°C.

Normal materials do not contain low-melting-point, easy-to-burn alloy elements, and the casting temperature can significantly increase.

The higher the casting temperature, the more fully the foam pattern will decompose. The casting temperature is high, the liquidus temperature is low, and the superheat temperature may exceed 300°C. From the beginning of casting to primary crystallization, there is enough time for the foam pattern to decompose and gasify. Gray cast iron tends to solidify sequentially and has good fluidity. Carbon and carbides trapped in molten iron during the casting process are still likely to float to the surface during the solidification process. Therefore, under the same beads and process conditions, gray cast iron is more conducive to reducing carbon defects and avoiding the impact of carbon defects on the inherent quality of castings.

Based on excellent solidification characteristics, gray cast iron products, such as gearbox casings, clutch housings, engine blocks, motor casings, valve bodies, and pump bodies, and TMMA-FD beads are used to replace non-casting-specific EPS, which can significantly reduce carbon defects and greatly increase the product qualification rate.

(2) The machined surface of gray cast iron products that should meet exceptionally high intrinsic quality requirements such as high-level safety parts and high-pressure parts takes up a high proportion, and should be assembled in strict accordance with the requirements. For gray cast iron products that are highly sensitive to casting defects, copolymer should be directly selected. The copolymer is more fully decomposed and better gasified, and the carbon defects are minimal under the same casting temperature and process conditions.

(3) The carbon equivalent of ductile iron is generally 4.1%~4.7%, and the liquidus temperature is relatively high, about 1,250°C~1,270°C; to reduce the spheroidization process and the Mg element burnt loss after the spheroidization, extend the spheroidization time and ensure the spheroidization level, the casting temperature should not be too high, generally 1,450°C as the upper limit. A low casting temperature is not conducive to the full combustion and decomposition of the foam pattern, and the superheat temperature of molten iron is lower than 200°C. From the beginning of casting to the primary crystallization, there is no enough time for the foam pattern to burn and decompose. Ductile iron tends to solidify at the same time and has poor fluidity. Carbon and carbides trapped in molten iron during the casting process have difficulty floating during the solidification process.

Compared with gray cast iron under the same foam pattern material and process state, ductile iron are more prone to carbon defects. Beads that can fully decompose and gasify must be used to minimize solid residue and effectively reduce the probability of carbon defects.

Therefore, a copolymer (STMMA) with good gasification effect and low residue must be selected for ductile iron.

(4) Common cast carbon steel has a carbon content of less than 0.5%, a liquidus temperature of about 1,500°C, and relatively poor fluidity. To ensure the casting quality, the casting temperature generally exceeds 1,620°C, or even close to 1,700°C. The higher the melting and casting temperature, the more serious the oxidation. Too high temperature may cause "overheating", "over-burning" and the formation of coarse grains. Therefore, the superheat temperature should not exceed 200°C.

In consideration of high liquidus temperature, low superheat temperature, early crystallization, fast solidification and extremely poor fluidity, there is no enough time for foam pattern decomposition, and carbon and carbides trapped in molten steel have difficulty floating.

Carbon steel has poor casting performance, so only copolymer (STMMA) or EPMMA products with better performance can be selected to effectively reduce and eliminate carbon defects.

(5) Blast furnace cooling walls and high-manganese wear-resistant steel products do not have high requirements for carbon defects, but ordinary EPS materials produce large-area carbon defects, and appearance repair requires high costs. Even counterweight castings needing to be painted must be repaired and then painted. Therefore, casting-specific foam materials should be used to reduce carbon defects and total productions costs and improve appearance quality.

(6) Some products such as machine tool beds, large-size machine bases, and automobile covering molds feature small batches and varying specifications. Foam patterns are not suitable for forming, and they are mainly used for sheet bonding or engraving.

It must be noted that ordinary EPS sheets are not casting-specific materials and will inevitably produce large numbers of carbon defects.

According to market needs, Zhejiang Castchem New Material Co., Ltd. has successfully developed casting-specific STMMA and STMMA-FD sheets, and achieved very good results.

Ordinary EPS sheets are pre-foamed using 0.9mm or larger beads, and single bead has a large volume. A relatively deep depression will be formed on each cut bead, forming a "pockmarked" face as a whole. Even if the density of the sheet is increased, there is no significant improvement.

The casting-specific sheet is pre-foamed using beads below 0.9mm, and single bead has a small volume. No obvious depressions are left after cutting, and appearance quality is satisfactory. It also has better engraving performance than EPS sheets pre-foamed using large beads. Casting-specific STMMA and STMMA-FD sheets have much higher strength than EPS sheets. It can not only greatly reduce carbon defects, and improve product appearance quality, but also effectively prevent product deformation.

V. Introduction to Copolymer Sheet for Lost Foam Casting

1. Product introduction

Copolymer sheet is a pattern sheet made from STMMA resin, which is pre-foamed, cured and then thermoformed by special sheet working machine. The sheet is shaped like a white or blue rectangle. The sheet has a density of 16~22kg/m3, and can also be customized according to customer needs. It is mainly used for castings made of ductile iron, cast steel and other materials. It is especially suitable for small-batch and heavy castings, such as automobile covering molds, large machine tools, large pumps, large fans and other castings.

The sheet is carved by CNC machine tool into a foam pattern that is almost consistent with the castings in shape, structure and size. After being painted with special refractory paint and dried, the lost foam process or resin sand process is used, and molten liquid metal is casted in, so that liquid metal flows into the model and the castings almost identical to the foam pattern are made.

The quality of the sheet is the most fundamental factor restricting the quality of lost foam casting. Taking heavy castings such as automobile covering molds and machine tool parts as examples, for thick and large castings such as automobile covering molds and machine tool parts in China, EPS sheets are generally used to make foam models for casting. Quality problems such as recarburization, carbon defects and slag inclusion are common in production, and such problems are more serious especially in ductile iron parts and cast steel parts. Castings having carbon defects will not only have rough processing surfaces, but in serious cases will affect the service life of the mold or machine tool.

After market research and discussions with many casting companies, it is found that in casting of automobile covering molds and machine tool parts, EPS sheets are generally made with EPS sheets and then casted, and the following problems exist:

(1) Recarbonization

During the casting process, the EPS natural foam pattern undergoes thermal decomposition in high-temperature molten iron. Part of thermal decomposition products will be discharged from the pattern in gaseous and liquid forms, and the other part will accumulate in the gap between the coating and molten iron or between the pattern and molten iron, forming free carbons. The diffusivity of free carbons in high-temperature molten iron and on the solidification surface is much greater than the diffusion coefficient during filling and condensation. There is convective mass transfer and diffusion mass transfer of carbon into molten iron, ultimately causing recarbonization, carbon slags, slag inclusion and other carbon defects in the castings.

Recarburization and carbon defects are common in ductile iron parts and steel castings, because the EPS sheet itself has a high carbon content and is not easy to decompose at high temperature. EPS sheets are used for foam patternmaking and casting, and recarburization and carbon defects are unavoidable for the castings.

(2) Deformation

Theoretically, low-density EPS sheets used in castings of the same volume have fewer recarbonization and carbon defects than high-density EPS sheets. For example, the total carbon content of a sheet with a density of 14kg/m³ is lower than a sheet with a density of 18kg/m³ under the same volume, so fewer recarburization and carbon defects will happen. However, low-density sheets have lower strength, and another problem is that the castings are easy to deform, especially in the production of thick and heavy castings such as automobile covering molds and machine tool parts. The carbon content, and the density and strength of the sheet are two contradictory opposites: to solve the problem of high carbon content and recarbonization of castings, companies will prefer low-density EPS sheets, but low-density sheets have low strength, causing deformation of castings.

(3) High cutting and repair costs

When EPS sheets are used to make foam patterns, and automobile covering molds and machine tool parts are casted, defects such as wrinkles, pores, slag inclusion, residue and recarbonization will occur on the surface of the casting. To solve the above problems, casting companies generally patch the foam pattern and use the uphill casting process during casting, that is, the casting surface is above the assembly bottom surface. Furthermore, when making a foam pattern, the bottom is patched with a thickness of 15~20mm. After casting, the patches are milled off with planomiller. According to the requirements of automobile covering mold companies, if there exist carbon defects on the casting face or obvious carbon defects on the bottom surface, in serious cases, the entire casting must be scrapped and redone. If visible carbon defects are still found within the allowable range after the bottom surface is cut, such defects shall be repaired by arc gouging, repair welding, grinding and other processes.

According to statistics, the cutting costs are generally calculated as RMB 300 for 2 working hours per ton of castings, while the repair costs are calculated as RMB 450 for 3 working hours per ton of castings. Therefore, recarbonization and carbon defects on the surface of automobile covering mold castings not only significantly increase the cutting costs, but also extend the lead time of mold castings.

To eliminate visible carbon defects on the machined surface, casting companies generally prefer uphill casting and patching (that is, patching the foam pattern). Casting companies will patch the pattern by 10~15mm for general castings, and will patch the pattern by 15~20mm, or even more for castings that should meet higher quality requirements. These patches need to be cut by machine tools after casting, which will inevitably lead to a doubling of cutting costs. Moreover, visible carbon defects on the machined surface can be eliminated through patching and repair, but invisible carbon defects inside the castings cannot be eliminated and avoided through patching.

2. Characteristics of copolymer sheet

The copolymer sheets include STMMA and STMMA-FD copolymer sheets (FD sheets for short). STMMA copolymer sheets are mainly used for the casting of ductile iron and steel castings, and the FD sheets are mainly used for the casting of gray cast iron.

The copolymer sheets do not contain any flame-retardant ingredients, and have the characteristics of low carbon and fewer slags, sufficient combustion, high gas evolution rate, and easy decomposition. Recarburization and carbon defects can be significantly reduced. Compared with EPS sheets, STMMA casting-specific sheets have the following advantages:

(1) Low carbon content, easy decomposition and less recarbonization

EPS has relatively high carbon content (92%), and its molecular structure is a relatively stable benzene ring structure (as shown Figure 1.3(a)). It is not easy to decompose when heated, and EPS is broken and decomposed in a disordered manner. It is not easy to gasify instantly, and residues that are not easy to decompose are generated.

STMMA has a small carbon-to-hydrogen ratio (shown in Figure 1.3(b)) and low carbon content (63%), and is broken and decomposed in a zipper-like manner at high temperature, having more honeycombs inside, which increases the contact area between the material and the air and accelerates the burning rate of the material. The molecular structure contains oxygen atoms. During heating and combustion, oxygen atoms react with carbon atoms to generate gas, so few residues are generated.

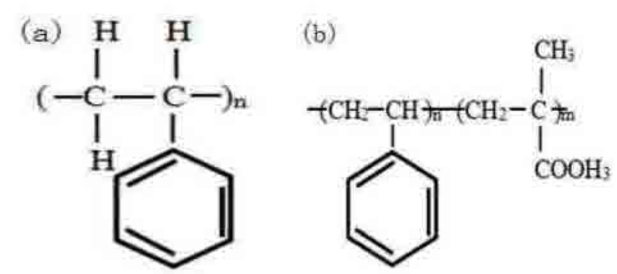


Figure 1.3 Molecular structure of beads, (a) EPS; (b)STMMA

(2) Good gasification, few residues and fewer carbon defects

STMMA casting-specific sheets are well gasified, and most foam models are decomposed into products such as CO, CO_2, water, and carbides during the casting process. Low molecular gases can escape through the coating layer, so few residues are generated in the foam pattern. Experimental data shows that for EPS and STMMA copolymer sheets of the same density, the residues on the STMMA copolymer sheets under high-temperature casting conditions are about one-tenth of that of the EPS sheets. Therefore, STMMA casting-specific sheets can significantly reduce carbon defects such as carbon deposits, carbon slags, and slag inclusion.

(3) Reducing the amount of patching, eliminating secondary processing of castings, and improving the quality of castings

Since STMMA casting-specific sheets have excellent casting properties such as low carbon content, easy decomposition, less recarbonization, good gasification, and fewer residues and carbon defects, castings made of STMMA casting-specific sheets have high surface finish and less recarbonization and carbon defects, and the machined surface is smooth and flat, and the quality of castings is greatly improved. Only then can casting companies reduce the amount of patching, eliminate secondary processing of castings, and thereby reduce the total production costs of castings. Moreover, the production cycle of castings has also been shortened, thereby achieving the goals of rapid production and delivery.

The appearance of the sheets is shown in Figure 1.4, and the sheet production site is shown in Figure 1.5.

Figure 1.4 STMMA sheets (light blue) and FD sheets (white)

Figure 1.5 Sheet production site

3. Application of STMMA copolymer sheets

STMMA casting-specific sheets have attracted widespread attention and great interest from the automobile mold industry and machine tool casting industry since its launch. We have applied STMMA copolymer sheets produced by a mold casting company of Anhui Province and a mold casting company of Hebei Province, the most famous domestic companies in batches, with a very significant effect.

(1) A company of Anhui Province mainly produces automobile covering molds and provides them to well-known domestic automobile companies. The casting blank has the maximum weight of about 30T. EPS sheets have been used for foam patternmaking. Problems of easy deformation, numerous carbon defects, large machining allowances, high cutting costs, high repair costs, long lead time, and high mold scrap rate are mainly found.

Test plan: Use Castchem STMMA copolymer sheets with a pre-foaming density of 22±1kg/m³. The pattern making and coating processes remain unchanged, and the casting rate in the black area remains unchanged. The casting temperature is between 1,450~1,500℃ and the negative pressure increases accordingly. No reverse squish is found during the casting process.

Test results: The casting results show that on an area of 12m2, there are only 3 carbon defects in the processing area of 3-5mm, 2 of which are minor. The machined surface is very smooth and beautiful, and the overall casting quality has been greatly improved. Compared with EPS sheets, carbon defects have been greatly increased. The machining allowance can be controlled at about 10mm, which is half that of EPS. It can greatly save cutting and repair costs, shorten the lead time, and reduce the scrap rate, as shown in Figure 1.6:

Figure 1.6

(2) A company of Hebei Province mainly produces automobile covering molds, and is a direct subsidiary of a famous domestic automobile brand and a well-known domestic automobile covering mold casting company. The casting blank has the maximum weight of about 30T. EPS sheets have been used for foam patternmaking. Problems of easy deformation, numerous carbon defects, large machining allowances, high cutting costs, high repair costs, long lead time, and high mold scrap rate are mainly found.

Test plan: Use Castchem STMMA copolymer sheets with a pre-foaming density of 18±1KG/m³. The full mold manufacturing and coating processes remain unchanged, and the casting speed in the black area remains unchanged. The casting temperature is between 1,450~1,500°C, and negative pressure is increased accordingly. No reverse squish is found during the casting process.

Test results: The casting results show that carbon defects are greatly reduced, the machined surface of the casting is very smooth and beautiful, and the overall casting quality is greatly improved. Compared with EPS sheets, the cutting and repair costs are reduced by more than 50%, and the scrap rate is reduced by more than 80%. The lead time is shortened, and the quality of castings is greatly improved, as shown in Figures 1.7 and 1.8.

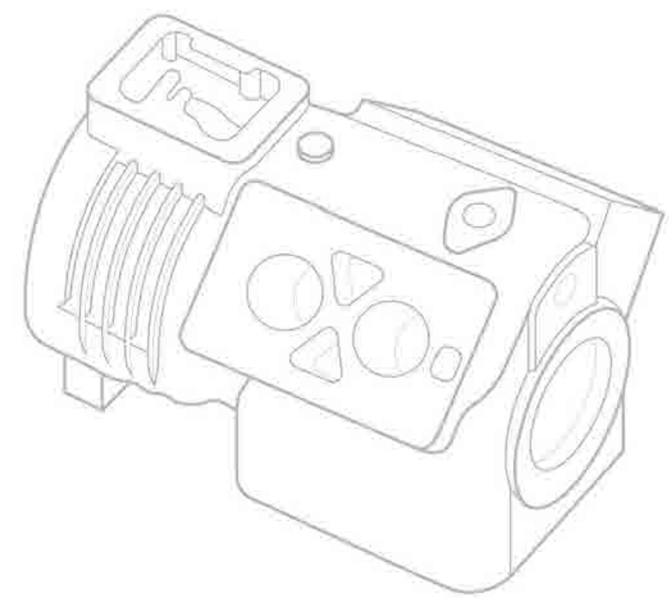
Figure 1.7

Figure 1.8

After using STMMA copolymer sheets on a large scale continuously, the above two companies have achieved good results and decided to use STMMA copolymer sheets for a long time. More automobile mold casting companies and machine tool casting companies have also found that to reduce carbon defects and improve casting quality, casting-specific sheets must be used, and the advantages of STMMA copolymer sheets should be fully recognized .

Chapter 2

Making of Foam Patterns and Combination of Model Clusters



I. Preparations for Lost Foam Casting

No casting process is omnipotent. When choosing different casting processes, we should consider product quality, yield and production efficiency, and find a more suitable casting process for each casting product. Lost foam casting is no exception. When you get the product drawings, you must first understand the following points:

(1) Understand whether the Company's existing equipment (such as forming machines, sandboxes, and smelting equipment) meets the requirements for product size and weight.

(2) Understand the material and technical requirements of casting products to facilitate the selection of appropriate foam raw materials (FD, STMMA or EPMMA), and communicate with the mold manufacturers on the shrinkage of the products according to the Company's melting and casting conditions.

(3) Understand the specific size and technical requirements of the drawings, and determine the machining allowance of the castings according to the drawings. For more important castings or ones that should meet special requirements, it is recommended that the machining allowance be greater than 3mm.

(4) Understand pattern parting and communicate with mold manufacturers on mold parting. It is recommended that mold parting be minimized if integral forming is feasible. For example, for some products that should meet air tightness requirements, if the operating conditions are convenient, handmade molds are recommended for integral forming. Here, the main consideration is to treat the cemented side seams. Nowadays, automatic gluing machine of various models and functions are emerging one after another. In view of the appearance and special requirements of the castings, the total cost of integral forming is more reasonable.

(5) Understand relevant processes and tooling. After the mold is finally selected, the preliminary plan for preliminary trial production shall be considered, and the corresponding tooling equipment and raw and auxiliary materials should be actively prepared to shorten the later trial production time whenever possible and strive for early batch supply.

II. Selection of Foam Beads and Density

1. Recommendations for selecting foam beads

(1) Selection of foam bead categories

When selecting foam beads, generally after the material of the casting product is determined, the category of foam beads is basically determined. In actual production, FD or EPS beads are generally recommended for gray cast iron (HT) castings. Copolymers (STMMA) can be used if conditions permit or there are special requirements; copolymers are best used for ductile iron (QT) castings, because the furnace temperature of ductile iron is limited by the spheroidization process (high furnace temperature may cause later spheroidization, serious alloy burning loss, and the spheroidization effect will be seriously affected). In addition, the fluidity of molten iron made of ductile iron is not as good as that of gray cast iron. For some thin-walled parts or castings with seriously unbalanced wall thickness, various defects caused by incomplete foam gasification will occur when molten iron is filled, which is also the reason why most manufacturers are unable or dared not to produce ductile iron castings in the early stages of lost foam development.

Since copolymer (STMMA) was launched in 2000, lost foam production of ductile iron castings has begun to expand on a large scale and has developed rapidly in recent years, which is mainly reflected in auto parts (rear axle reducer housings, boxes, hubs, etc.), ductile iron pipes/ pumps/valves, agricultural machinery accessories, etc.

Currently, several Chinese lost foam manufacturers have been producing ductile iron feed and drain pipe accessories (pipe fittings, tees, elbows, flanges and sockets, etc.) with thin wall thickness and large diameter, and still use FD materials or EPS beads, mainly because most of these accessories are buried underground after being coated according to use environment, and the pressure requirements are low. FD and EPS beads have some advantages in cost saving.

Considering that there are stringent pattern requirements for steel castings, there is no consensus on whether to use EPS beads or STMMA beads. It is believed that the decision should be made based on the product structure and technical requirements. Although STMMA has more advantages than EPS in solving defects such as appearance and recarburization of steel castings, it is still not ideal. Therefore, after three years of research, the modified copolymer resin and EPMMA successfully developed by Castchem will become a new breakthrough in the pattern materials of steel casting owing to their unique superior properties.

(2) Recommendations for selecting foam bead size

In lost foam casting, foam pattern making is critical. During foam pattern making, attention should be paid to the selection of original beads. First, the beads for lost foam casting should be reasonably selected according to the material, performance and process requirements of the castings. If STMMA, FD or EPS beads are finally used, the appropriate bead size should be selected.

When the beads are pre-foamed at an foaming ratio of 40 ~ 50 times, the diameter of the beads increases approximately 3 times, as shown in Figure 2.1.

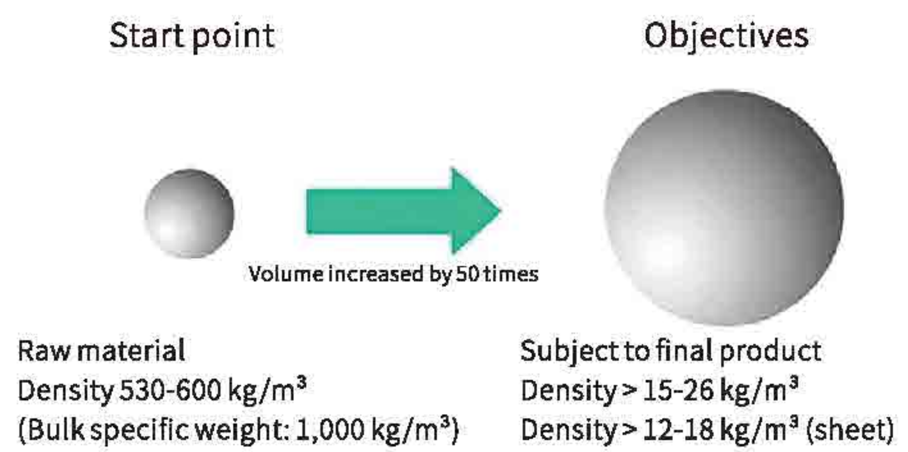


Figure 2.1 Schematic diagram of increasing bead diameter when beads are pre-foamed 40 ~ 50 times

To obtain better surface quality of the foam pattern, during secondary foaming (forming), 3 beads should be arranged at the minimum wall thickness of the pattern, as shown in Figure 2.2:

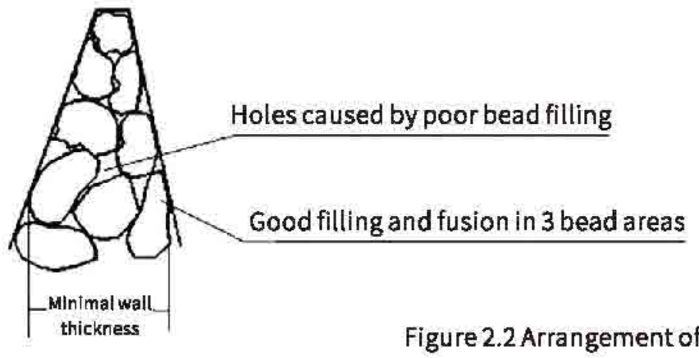


Figure 2.2 Arrangement of beads

Principles for selecting bead specifications (size): When choosing the size of any kind of beads, customers must first understand the size, wall thickness, surface quality requirements, etc. of the castings to be produced.

Generally, we select the bead size (specification) based on 1/10 of the minimum wall thickness of the castings, that is: foam bead size = minimum wall thickness of the casting/10, and then select the bead type corresponding to the foam size according to the comparison table of bead size and specification as provided by the raw material manufacturer. If the casting surface requirements are high, smaller beads can be selected. A summary of different foam bead sizes in China is shown in Table 2.1.

Table 2.1 Summary of Different Foam Bead Sizes

STMMA		STMMA~FD		KING PEARL	
Spec./model	Bead size	Spec./model	Bead size	Spec./model	Bead size
STMMA~1#	0.71~0.90	Special specifications	0.90~1.25	H~MS	1.00~1.60
STMMA~2#	0.65~0.85	FD 1# (largesize)	0.71~0.90	H~SA	0.80~1.20
STMMA~3A	0.50~0.65	FD 1# (smallsize)	0.60~0.80	H~SB	0.60~0.90
STMMA~3#	0.35~0.50	FD~2#	0.40~0.65	H~S	0.40~0.70
STMMA~4#	0.25~0.35	FD~3#	0.35~0.45	H~4S	0.30~0.50

Jiachang		Xingda		Tianjin KING PEARL	
Spec./model	Bead size	Spec./model	Bead size	Spec./model	Bead size
B~103	1.00~1.60	301	1.00~1.60	H~MS	1.00~1.60
B~104	0.85~1.25	302	0.85~1.25	H~SA	0.80~1.20
B~105	0.70~1.00	303	0.70~1.00	H~SB	0.60~0.90
B~106	0.50~0.80	401	0.50~0.80	H~S	0.60~0.75
B~107	0.40~0.60	501	0.40~0.60	H~SS	0.50~0.60
B~108	0.30~0.50	601	0.30~0.50	H~4S	0.35~0.50

2. Recommendations for selecting pre-foaming density of foam beads

Each bead manufacturer will recommend a pre-foaming density based on its foaming ratio. We can choose an appropriate pre-foaming density based on forming conditions and appearance requirements of the foam model. For some foam patterns that should meet high appearance requirements, smaller beads can be selected. In general production, under the premise of ensuring that the strength and shrinkage of the foam patterns are satisfactory, the lower the foam density, the smaller the possibility of producing wastes in later casting.

Practical case of bead selection:

Product name: Ductile iron shell

Material: Ductile iron 450~10

Wall thickness: Min. 6mm, Max. 26mm

Weight of casting blank: 37kg

Processing requirements: No defects in end face processing, no shrinkage in hole processing.

As described above, STMMA copolymer beads (STMMA~2#) should be selected; if the surface quality requirements of the castings are higher, it is recommended to choose smaller beads, that is, STMMA~3A beads, as shown in Figure 2.3.

III. Pre-foaming Process of Foam Beads

Pre-foaming of foam beads is to obtain a foam pattern or foam sheet with low density and uniform cells. Resin beads must be pre-foamed before pattern forming. The pre-foaming quality of beads has a great influence on the forming process and quality. There are diverse methods depending on the heating medium and method, but currently the most common method is steam pre-foaming.

Figure 2.3

Principle of steam pre-foaming: When the resin beads are heated by steam to the softening temperature, the beads do not foam, but the foaming agent escapes. When the temperature rises to the softening temperature of the resin beads, the beads begin to soften and have plasticity. The foaming agent in the beads is heated and gasified to generate pressure, so that the beads expand and a disconnected honeycomb structure is formed.

Once the cells are formed, steam penetrates into the cells, in which the pressure in the cells gradually increases and the cells further expand; during cell expansion, the foaming agent also diffuses outward and escapes. It does not stop expanding until the pressure inside and outside the cells is equal. After cooling, the size of the foamed beads is fixed, as shown in Figure 2.4:

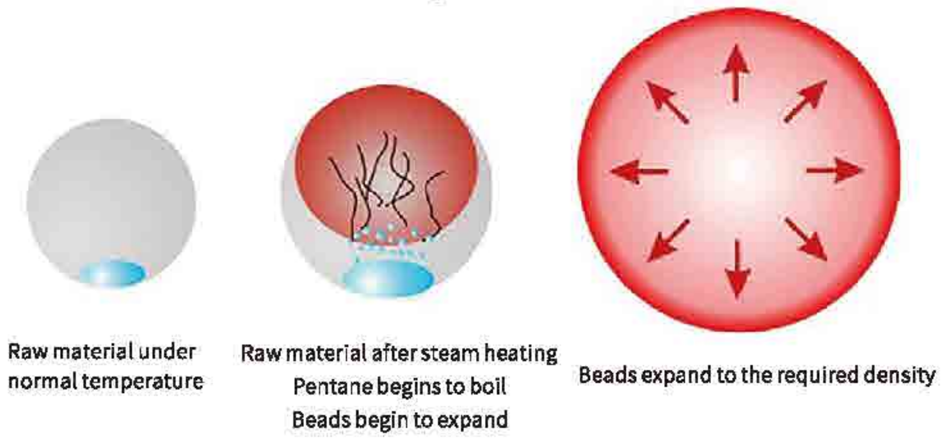


Figure 2.4 Expansion process of foam beads during pre-foaming

1. Equipment requirements for pre-foaming

Difference between lost foam white area equipment and molds/packaging molds: the patterns for lost foam and packaging molds are also made by white area equipment and molds, but they are not the same thing systemically. Lost foam casting should meet many technical requirements for patterns. Therefore, there are also relatively high requirements for related equipment and molds. To make a lost pattern, the concept must be changed starting from packaging molds.

Selection of lost foam white area equipment: Lost foam casting companies must choose professional equipment suppliers. Professional equipment suppliers will sell you not just a few sets of equipment, but a complete lost foam system, complete after-sales service and complete process technology concepts.

2. Steam requirements for pre-foaming

Steam state in pattern making process: During the bead pre-foaming and pattern forming, we put forward steam requirements of "low pressure and high flow, saturated and slightly superheated, and stable pressure". Some may ask why?

①Low pressure and high flow: Allowing steam to penetrate beads instantly (shortening the steam penetration time during pre-foaming and forming), A. Pre-foamed beads are uniform and non-agglomerated; B. Keeping the pattern from shrinking in thin areas and expanding in thick areas.

②Saturated and slightly superheated steam: Reducing the moisture content in the steam and improving the thermal efficiency (wet steam: 1500KJ-360%, saturated steam: 2675KJ-650%, superheated steam: 2762KJ-670%).

③Keeping steam pressure stable: Keeping the density of pre-foamed beads consistent for a long time and the foamed pattern consistent.

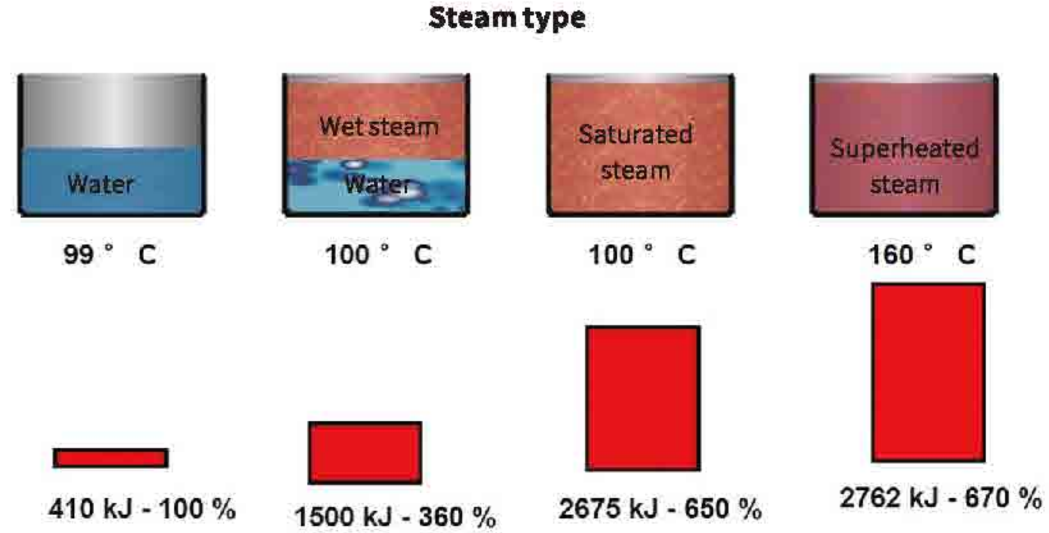


Figure 2.5 Schematic diagram of steam types

3. Recommended design and installation of intermittent pre-foaming machine steam pipes

See Figure 2.6:

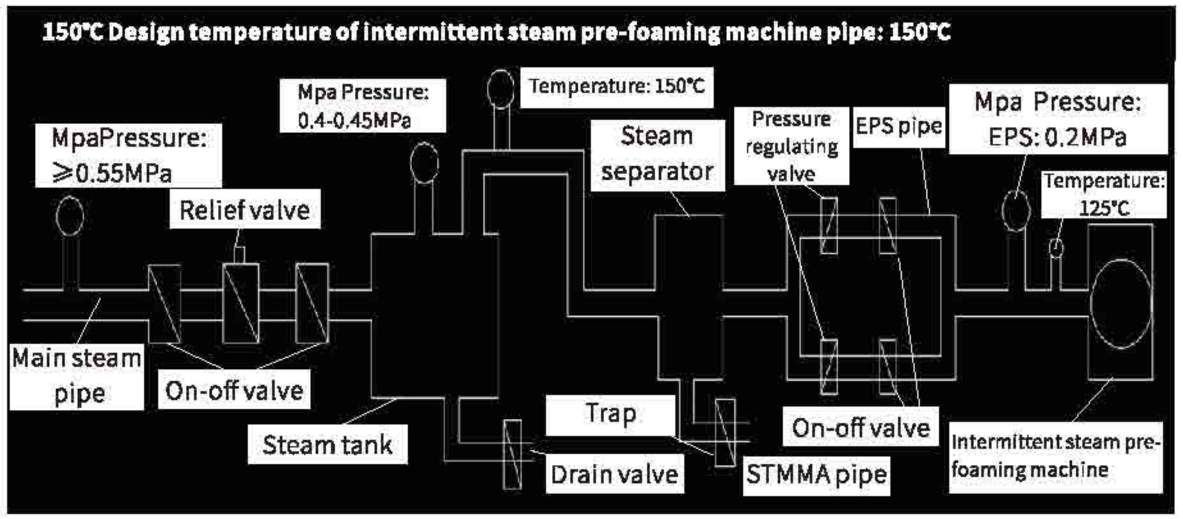


Figure 2.6 Schematic diagram of design and installation of intermittent pre-foaming machine steam pipes

Steam pipe requirements for intermittent steam pre-foaming machine

(1) After steam pipes are depressurized, the pressure of the steam tank should be controlled at about 0.45Mpa (about 150℃);

(2) Steam before entering the pre-foaming machine needs to flow through the steam separator to fully remove excess moisture in steam;

(3) After secondary pressure regulation, the pre-foaming machine pipe pressure must be stably controlled at 0.18Mpa.

4. Control of pre-foaming process and operating parameters

Beads are generally pre-foamed in an intermittent steam foaming machine. Operating parameters vary from pre-foaming machines, but the operating process is basically the same.

Process: Preheating - feeding - heating and foaming - discharging - drying - cleaning

(1) Preheating: To reduce the moisture in the pre-foaming barrel and shorten the pre-foaming time. When the preheating temperature reaches the required value, the prepared beads can be fed to the pre-foaming machine.

Note: Preheating is divided into two steps: a. Steam preheating; b. Inlet and exhaust steam cycle preheating. Inlet steam is preheated to maintain the temperature in the pre-foaming barrel at 90~105°C; then inlet and exhaust steam is preheated in cycles (15~20 minutes) to keep the temperature in the pre-foaming barrel stable (little fluctuation). During the preheating process, manual blowdown is required.

(2) Feeding: Taking 450 pre-foaming machine produced by Hangzhou Fuyang White Area Equipment Manufacturer as an example, the feeding volume is generally controlled at about 0.6kg (about 1,000ml).

(3) Heating and foaming: The steam pipe pressure is 0.45Mpa (after depressurization); the pipe steam pressure of the pre-foaming machine is controlled at 0.14~0.18Mpa (after depressurization).

Example:

Copolymer beads: The expansion chamber pressure is controlled at 0.02~0.05Mpa, the temperature 95~105°C, and the time 30~70 seconds.

FD beads: There is no pressure in the expansion chamber, the temperature is 83~93°C, and the time is 15~45 seconds.

(4) Drying: The pre-foamed beads should be dried on the fluidized bed to reduce the moisture of the pre-foamed beads (Note: the time of drying on fluidized bed should not be too long. Otherwise, mass static electricity will be generated among beads. The best temperature of fluidized bed is 25~40°C).

(5) Cleaning: After each pre-foaming, the fluidized bed and pre-foaming barrel must be carefully cleaned to avoid mixing in the next pre-foaming.

(6) Density of pattern: It should be controlled at 18~26g/L. When the density is less than 18g/L, the pattern is easy to deform; when the density is greater than 26g/L, a high gas evolution rate for casting may cause defects such as reversed squish.

The density control of beads depends on the size of the original beads and the thickness of the model. Generally refer to Table 2.2:

Table 2.2

Size of STMMA beads	1#	2#	3A	3#	4#
Size of FD beads	1# (large size)	1# (large size)	2#	3#	4#
Recommended density (g/L)	18~20	19~22	20~23	22~26	23~26

5. Determination of qualified beads after pre-foaming

(1) The moisture content of the pre-foamed beads should be low (considering steam quality and preheating of the pre-foaming machine) - the moisture content of the beads should be <5%;

(2) The pre-foamed beads should be uniform (considering the feeding volume, preheating, pre-foaming machine scraper, steam quality, pre-foaming time, and bead quality) - the density fluctuation of the pre-foamed beads should be controlled within ±0.5 g/L;

(4) The pre-foamed beads should be wet (considering the pre-foaming time, pre-foaming density, and pre-foaming temperature);

(5) The pre-foaming density should be controlled according to the curing requirements (considering the control of moisture content and volatile matter of beads) - the difference between mature beads and pre-foamed beads is 1~1.5g/L.

6. Pre-foaming process parameters (see Figure 2.7):

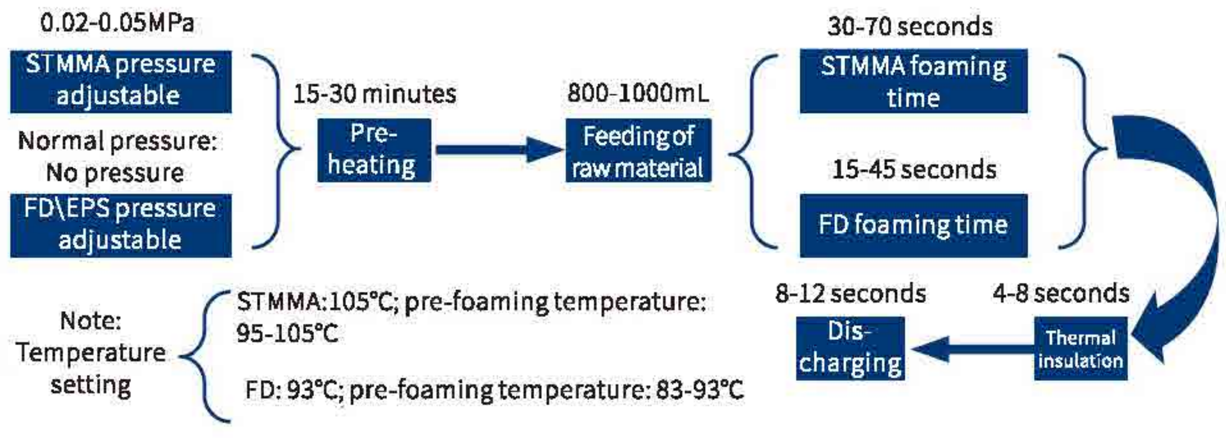


Figure 2.7 Pre-foaming process parameters

IV. Curing Time and Process Control

1.Requirements for curing barn during curing

(1)The volume of the curing barn should not be too large. The curing barn for curing foam beads in the lost foam white area is generally 1~3m³

(2)The curing barn net should not be too dense (less than the diameter of the smallest pre-foamed beads);

(3)The curing barn should be constructed of anti-static material and composed of plastic mesh or stainless steel mesh to prevent static electricity generated during bead conveying and combustion.

The pre-foamed beads are stored in a barn for curing - called "curing barn", as shown in Figure 2.8:

Figure 2.8 Curing barn

2.Environmental requirements for curing

(1)Curing barn: It should be placed under good ventilation conditions, so that foam beads can better meet the curing requirements and pattern forming defects caused by poor curing effect can be reduced.

(2)Optimum curing temperature of beads: 25~40°C; humidity <30%.

(3)Curing time: ≥24 hours for copolymer beads; 8~48 hours for FD\EPS beads (to be adjusted based on the user's equipment and special environmental conditions)

Note: If the curing environment cannot provide good ventilation conditions, compressed air or a fan should be used every 2 ~ 3 hours to stir up the beads in the curing barn or keep the barn reversed (purpose: to change the positions of the beads on the surface and inside the curing barn and ensure that the beads in the entire curing barn are well cured).

3.Recommendations on curing time control

After the newly pre-foamed beads are cooled, the foaming agent and water vapor in the cells cool and liquefy, forming a vacuum in the cells. During the curing process, air penetrates into the cells, keeping the pressure inside and outside the cells in the beads balanced.

The optimal curing temperature of beads is 25~40°C. The curing time is related to the moisture and density of beads and the ambient temperature and humidity.

For example: the relationship between the density of FD beads and curing time, as shown in Table 2.3:

Table 2.3

Bead density (g/L)	18	20	23	26
Optimal curing time (hours)	20~48	12~30	10~24	8~12

Pre-foamed FD beads are dried and cured through a hot air drying bed (fluidized bed), and can be formed after curing for ≥8 hours.

After STMMA copolymer beads are pre-foamed, the curing time is generally ≥24 hours. The curing of the pre-foamed beads is an important process for producing high-quality patterns.

4. Determination of qualified beads after curing

Good beads generally have good gloss, round surface and good resilience when pinched by hand; under poor pre-foaming effect, the surface will bubble, some will become oval and inelastic, and the volatile matters will escape relatively quickly.

In this curing process control, the best control points for volatile matters are as follows: copolymer beads: 7~7.5%; ordinary (FD\EPS) beads: ≥5%, to reduce the possibility of tertiary foaming or sparse fusion after bead foaming.

Normal beads and damaged beads after curing are shown in Figure 2.9.

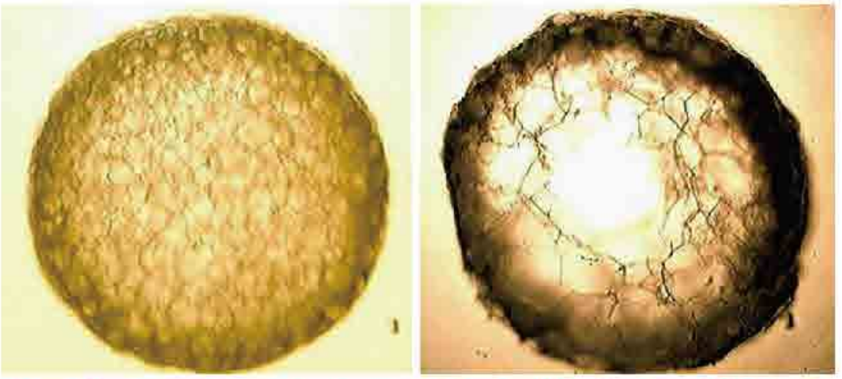


Figure 2.9 Beads after curing

V. Control of Forming Process Conditions

Methods for foam forming of patterns depend on heating methods, mainly including steam cylinder (steam box) forming and press air chamber forming.

1. Steam cylinder (steam box) forming

The process of steam cylinder (steam box) forming, commonly known as manual forming, is as follows: in consideration of complex mold structure, multiple movable blocks on the left and right or up and down need to be manually disassembled and assembled. When a large number of foam patterns are required, the patterns do not need to be bonded during the entire patternmaking process. After the cured beads are filled into a mold cavity by feed gun, they are placed in a steam cylinder (steam box), steam is introduced and the pressure, temperature and time are controlled. After foam forming, they are taken out from the steam cylinder (steam box), cooled, molded and demolded.

Since the re-expansion of the beads during team cylinder (steam box) forming is mainly the introduction of heated steam between the beads through the air plug holes, steam, air and condensed water exist between the beads, which requires ample time for discharging air and condensed water through the air plug hole. Therefore, the expansion speed of the beads formed in the steam cylinder (steam box) is slow, and the time is long. For example, the heating time of 7~30mm thick patterns is about 3~5 minutes. Steam pressure for steam cylinder (steam box) forming and heating is shown in Table 2.4:

Table 2.4

Pattern material	FD/EPS	STMMA
Steam pressure (Mpa)	0.08~0.10	0.10~0.14

The steam cylinder (steam box) forming mold is manually assembled and disassembled, with low production efficiency, and is not suitable for mass production. Steam cylinder forming is shown in Figure 2.10:

Figure 2.10 Steam cylinder forming equipment

2. Press air chamber forming

Mold press air chamber forming, commonly known as mold forming, is to fill the mold cavity having an air chamber with pre-foamed and cured beads through a feed gun. The horizontal parting of the mold is divided into two parts of an upper steam cabinet and a lower steam cabinet, in which the upper steam cabinet is fixed on the movable mold of the forming machine, and the lower steam cabinet is fixed on the fixed mold of the forming machine. The mold is opened or closed by lifting the movable mold upward or downward. Superheated steam enters the mold cavity through the air plug holes on the mold wall, passes through the gaps between the beads, and drives away air and condensed water, so that steam quickly fills between the beads and penetrates into the cells.

When the pressure inside the cells, that is, the total of the vapor pressure of the foaming agent, the saturated vapor pressure at the forming temperature, and the expansion pressure of the air is much greater than the external pressure on the beads. When the beads are heated and softened, the beads expand and are foamed again. Then cooling water is introduced from the air chamber, the mold and forming pattern are cooled and finalized, and the required foam pattern or mold can be obtained by demolding.

Low-density foam patterns are obtained through press air chamber forming, which is characterized by short forming time, stable process and good pattern quality. This method is the main forming method for lost foam patternmaking, as shown in Figure 2.11:

Figure 2.11 Press air chamber forming equipment

(1)Press air chamber forming process

The schematic diagram of the press air chamber forming process is shown in Figure 2.12:

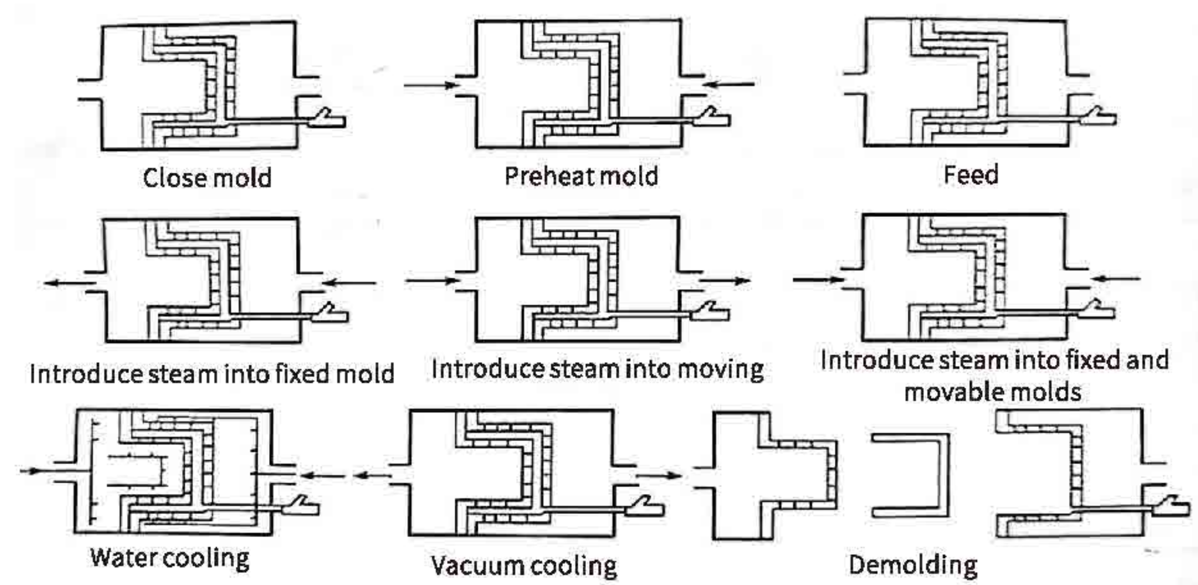


Figure 2.12

A. Close mold: Close the foaming mold. For large beads, the mold parting face generally has a gap smaller than the radius of the pre-foamed beads. Thus, compressed air can be discharged from the air plug hole and the gap at the same time when feeding, which is conducive to rapid filling of beads into the mold cavity; when heated by steam, air and condensed water between beads can be discharged from the mold cavity through the air plug holes and gaps at the same time. However, when special lost foam casting materials are used, due to the small size of the beads, generally no gap is left when the mold is closed, and air and condensed water between beads can only be discharged from the mold cavity through the air plug hole. It should be noted that flash is generally produced at the pattern parting face if a gap is left.

B. Preheat the mold: Preheating the mold before feeding is to reduce the condensation of steam during bead foam forming and shorten the foam forming time.

C. Feed: Open air outlets of the fixed and movable mold air chambers, and blow the pre-foamed beads into the mold cavity through the feeding port of the mold using a compressed air feeding tank. After the entire mold cavity is filled with the beads, the feed inlet is plugged with the feeding plug. Feeding is the basis of bead foam forming. An improper feeding method may lead to incomplete or uneven filling of beads in the cavity, and pattern defects will occur no matter how good the mold and beads are. Therefore, feeding is one of the important steps in the foam forming process.

At present, there are three feeding methods commonly used in production, namely suction filling, pressure filling and negative pressure filling.

①Suction filling is a feeding method commonly used by manufacturers in China, by which a common feed gun - a Vonturi gun is used and beads are sucked into the mold cavity under compressed air. For molds with simple cavity structures, this feeding method has a better effect. However, for molds with complex cavity structures, the mold cavity cannot be completely filled with beads, resulting in a lack of material in the pattern. The structure diagram of an ordinary feed gun is shown in Figure 2.13:

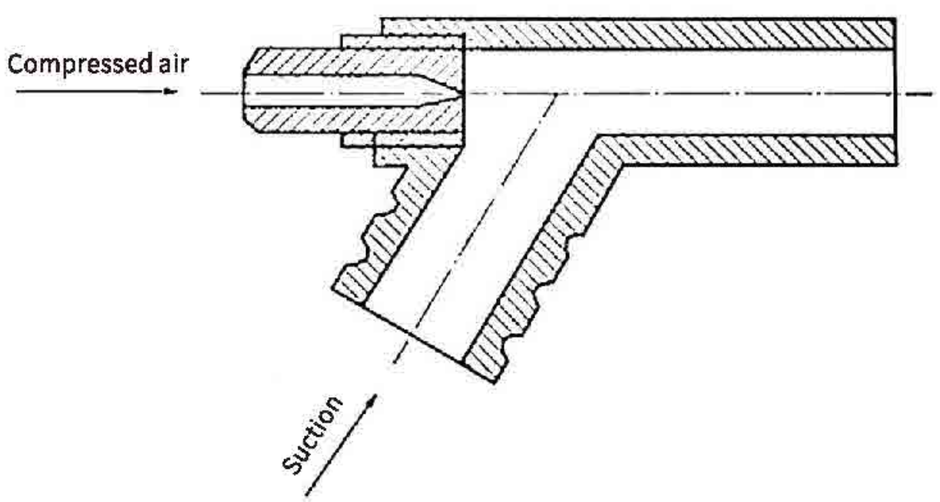


Figure 2.13 Structure diagram of ordinary feed gun

②Pressure filling. Positive pressure is applied on the beads when feeding, so that the mold cavity is filled with beads, with certain compactness, as shown in Figure 2.14.

Figure 2.14

③Negative pressure filling is to apply negative pressure on the back of the mold while suction filling, and the mold cavity is filled with beads under both negative pressure traction and compressed air suction.

To solve the problem of feeding beads into complex thin-wall patterns, the method of feeding by multiple feed guns at the same time can also be used. For the above feeding methods, feeding by multiple feed guns at the same time can achieve the best result.

(2) Filling of beads during forming

High-quality patterns are made depending on a complete filling system and complete technology. Perfect filling of the patterns is crucial for a good casting! Perfectly filling the cured beads into the mold cavity is an important step in patternmaking, which is a very important issue. Poorly filled patterns will result in pattern shortages and pattern density gradients. Foreign automatic forming machines can better solve this problem. Most domestic manufacturers prefer press forming, and the pressure filling system (feed tank) has been used. The filling pressure from the hopper to the mold cavity should be low, and the filling pressure should be even to ensure that the beads are reversed to the tank and avoid clogging of the filling line. A filling hose with a smaller diameter than normal should be used, which is reliable, but filling defects often happen.

Ⅰ. Pressure filling process (see Figure 2.15):

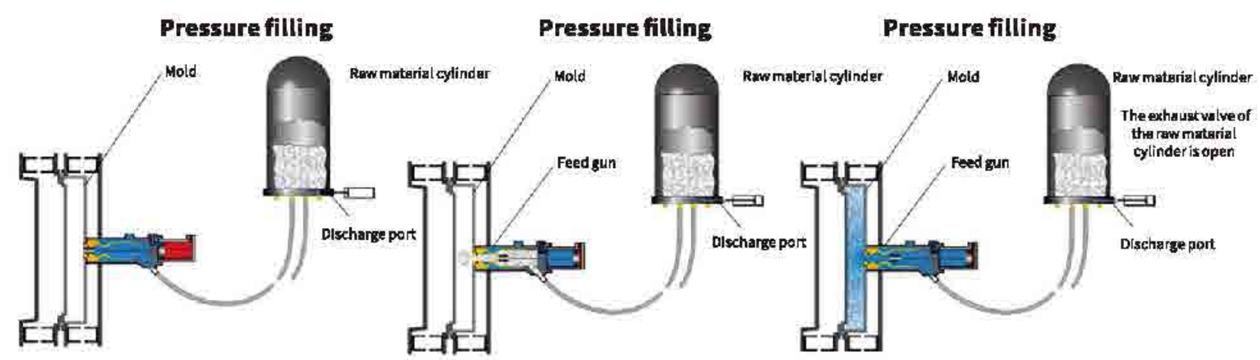


Figure 2.15 Schematic diagram of pressurized filling process

Ⅱ. Filling of patterns:

As we know, when the beads flow in, a large amount of compressed air is conveyed into the mold cavity, and it is very difficult for compressed air to overflow the mold through the air plug. As a result, the pressure inside the mold cavity will increase, and the mold that is not ventilated enough is under high pressure, resulting in uneven density of the beads, especially at the port of feed gun.

Non-consistent density of the patterns will cause casting problems. Patterns with thin walls and complex shapes are more difficult to fill. It is not recommended to lift the mold for filling. A dry mold can be better filled.

Ⅲ. How to effectively reduce pattern filling defects

①Pre-foaming control: During pre-foaming, ensure that pre-foamed beads have gloss, uniform size and low moisture content; when drying on a fluidized bed, the dwelling time should not be too long (to reduce static electricity).

②Curing control: When the beads are cured, all the beads should meet the curing standard, and the cured beads should have good resilience.

③Forming control: The mold should be preheated before filling, and condensed water in the mold cavity should be blown dry with compressed air. During suction filling, it should be noted that the feed tube is not too long (otherwise the resistance will increase). The pressure inside the tank is generally 0.2MPa (to be adjusted according to different situations) when filling into the feed tank. When filling, attention should be paid to the control of the amount of compressed air (to avoid eddy currents in the mold cavity); when the bead density is small (<18g/L), the mold should be appropriately lifted for feeding.

④Mold control: According to different mold cavities, the position of the filling port and the specifications of the mold air plug (size of the air plug hole) should be reasonably selected; the mold air plug should be regularly cleaned to avoid clogging by beads and sewage impurities.

(3) Control of forming process conditions

①Mold preheating

Cold air is driven away from the air chamber, because air has poor heat conductivity, as shown in Figure 2.16.

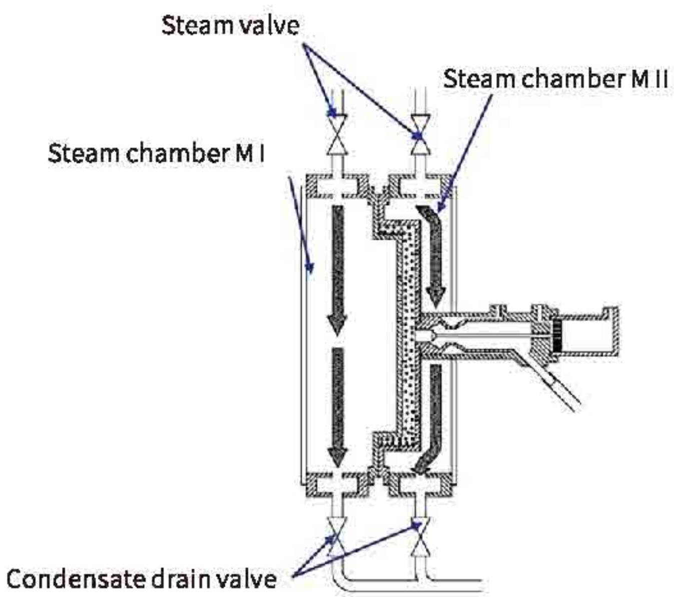


Figure 2.16

②Steam delay

The beads stay in the mold for a while to keep them stable in the mold. This method is suitable for more complex products.

③Introduction of steam into fixed mold

Steam enters the movable mold air chamber and enters the cavity through the air plug hole on the mold wall. Air and condensed water between beads are discharged from the movable mold cavity through the air plug hole on the mold wall.

④Introduction of steam into movable mold

Steam enters the movable mold air chamber and enters the mold cavity through the air plug hole on the mold wall. Air and condensed water between beads are discharged from the fixed mold cavity through the air plug hole on the mold wall, as shown in Figure 2.17.

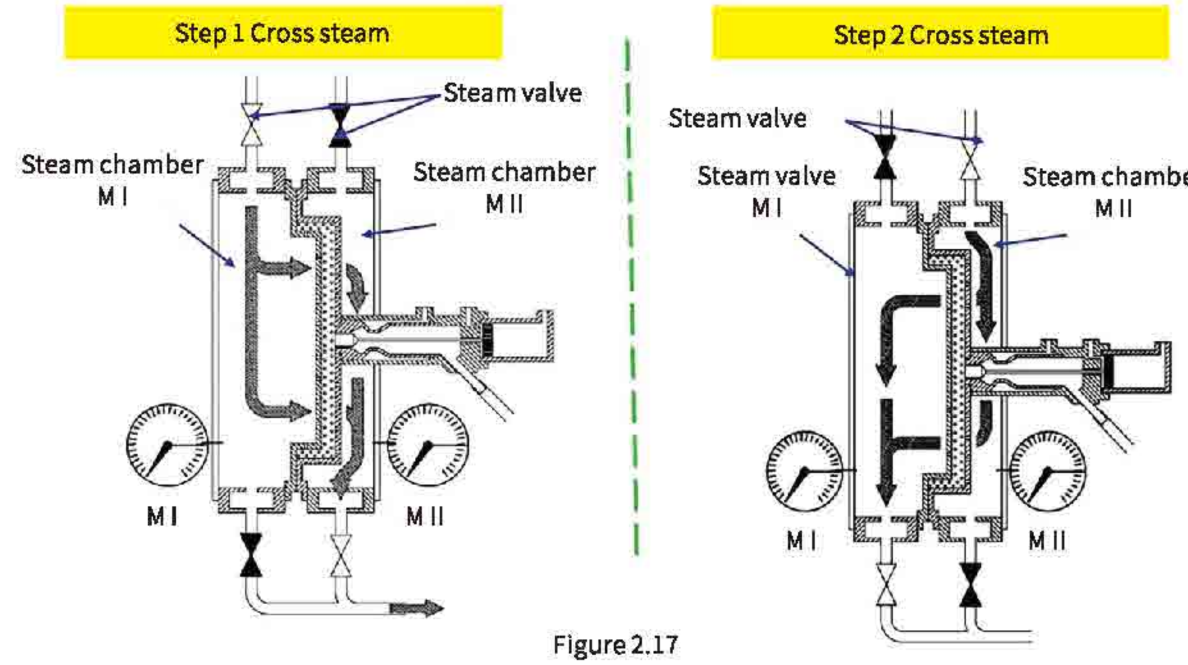


Figure 2.17

⑤Introduction of steam into fixed and movable molds

Steam is introduced into air chambers of fixed and movable molds at the same time and maintained at the set pressure for several seconds. The beads are heated and softened and expand again to fill the mold cavity, so that all the gaps between the beads are connected into a whole.

⑥Water cooling

Cut off steam, and introduce cooling water into air chambers of fixed and movable molds to cool the pattern and the mold to the demolding temperature, generally below 70°C.

⑦Vacuum cooling

Drain cooling water and open vacuum to further cool the pattern and reduce the moisture content in the pattern.

⑧Mold opening and demolding

Open the mold on the press and select an appropriate mold taking method, such as water vapor superposition, mechanical ejector or vacuum chuck to take out the mold, as shown in 2.18.

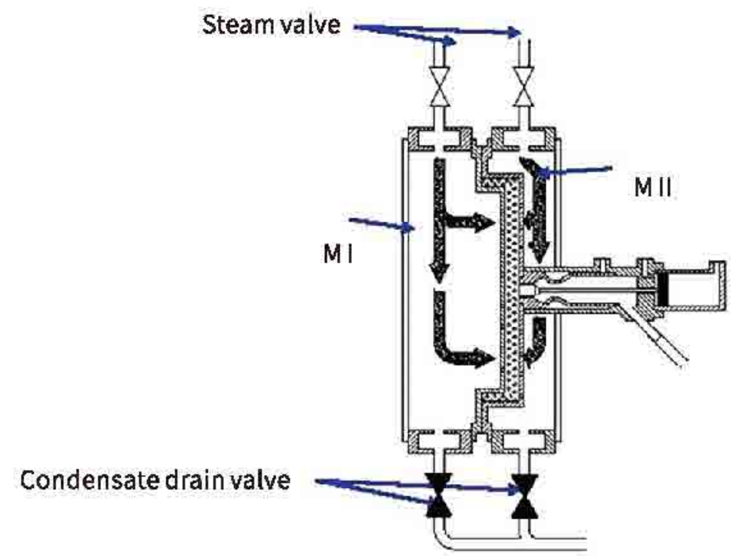


Figure 2.18

(4) Stable fusion of pattern during forming

The corners of the product and areas without air plugs can be better fused under the heat of the mold (namely thermal insulation), and can be used for more complex products.

Forming process: Keep surface fusion not dense and extend the holding time. Operation process: the time between steam cutoff and air release & water cooling (the holding time depends on different forming equipment and patterns, the general recommended holding time is 8~12s).

(5) Cooling of patterns during forming

①Traditional water cooling:

The water inlet valve remains open, water enters the mold, and heat is taken away under water flow until the mold reaches the required demolding temperature. Cooling water is sprayed onto the pattern through the steam plug. Generally, traditional water cooling is suitable for slow pattern forming.

Pay attention to cooling speed and water inflow of fixed and movable molds.

② Combination of water cooling and vacuum cooling:

Heat required to heat 1 kg of water from 20°C to 100°C: 335 kj, heat required to convert 1 kg of water (100°C) into 1 kg of steam (100°C): 2256kj. Spray atomized water onto the mold to absorb a large amount of heat, vaporize water, absorb heat by evaporating water, and initially cool the mold down. A vacuum is formed in the steam chamber, and water starts to evaporate, drawing out vaporous water and taking away heat. It is mainly used for quick pattern forming.

Principle of vacuum cooling (see Figure 2.19):

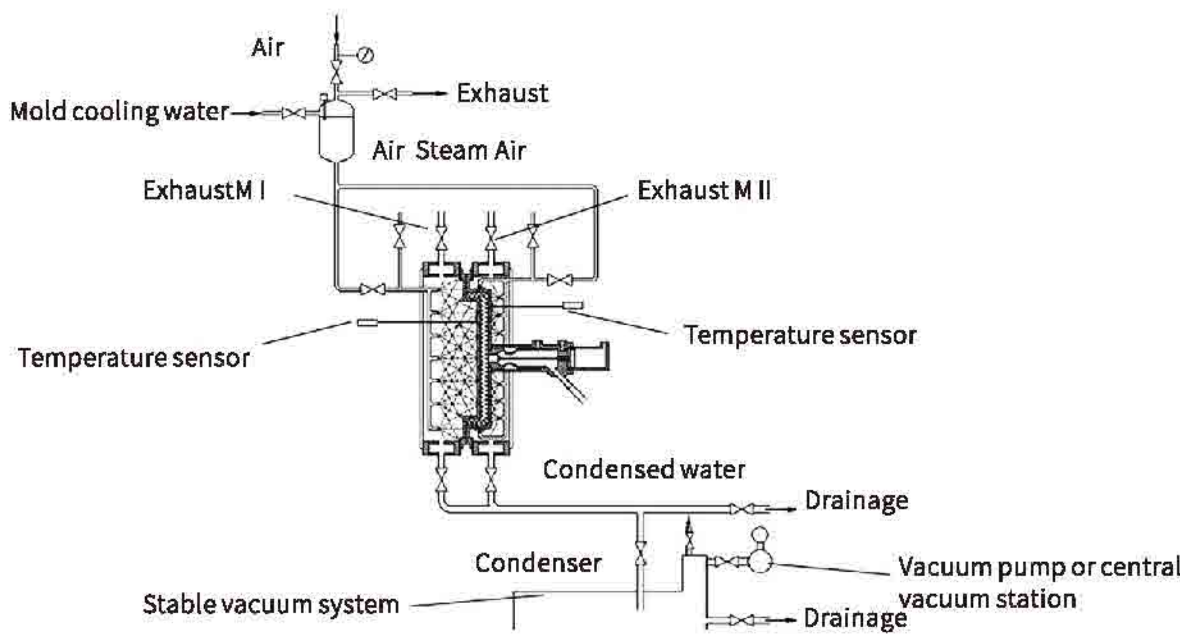


Figure 2.19

Advantages of vacuum cooling (see Figure 2.20):

Vacuum condensation system (see Figure 2.21):

(6) Precautions for press air chamber forming

When the heating steam pressure for press air chamber forming is selected, the type of original beads, bead specifications, pattern structure and the way the steam is introduced into the mold should be considered. To obtain a qualified pattern, 4 issues should be noted during the production process:

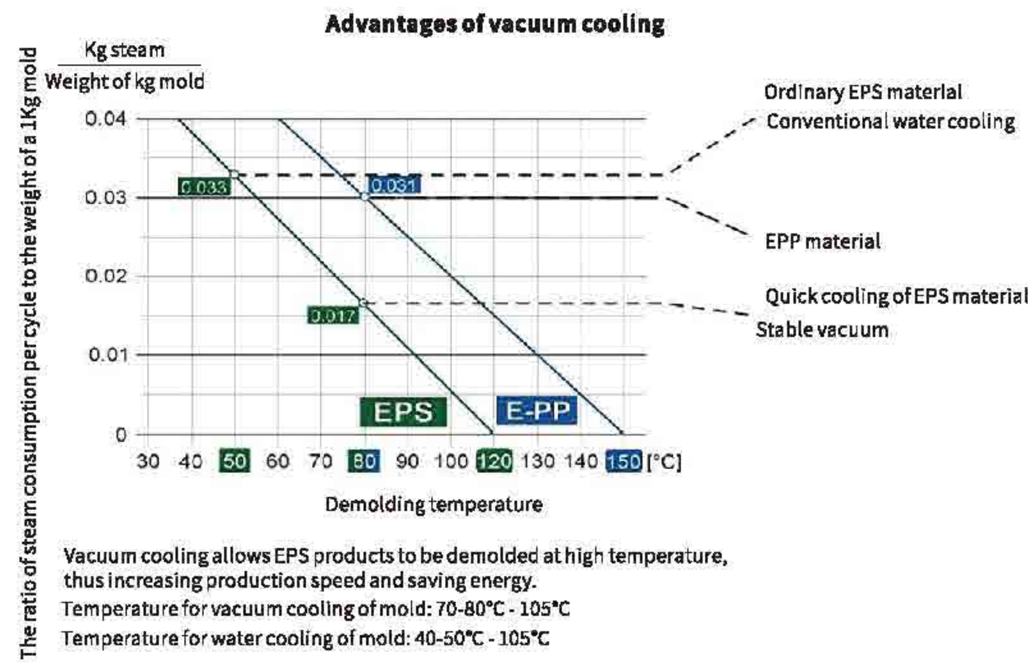


Figure 2.20

Vacuum condensation system (see Figure 2.21):

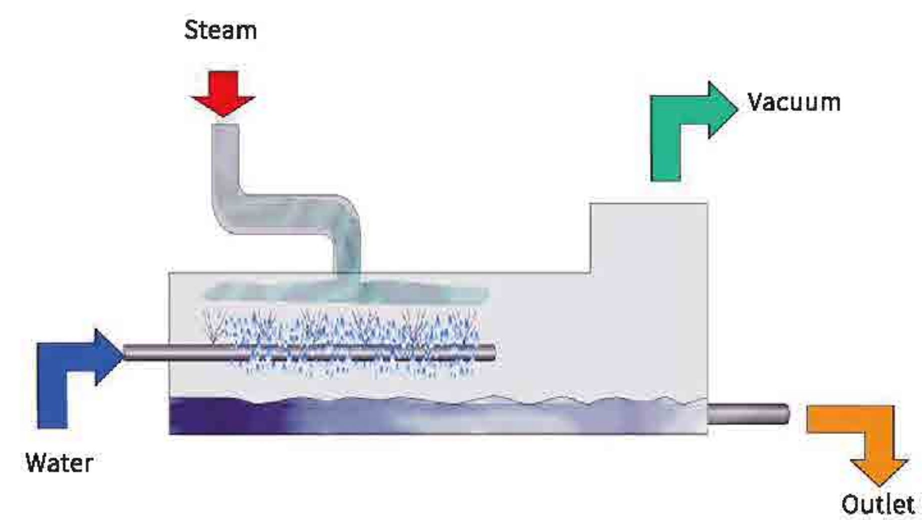


Figure 2.21

①The appropriate feeding method should be selected according to the structural characteristics of the mold to ensure that the mold cavity are evenly filled with beads. Insufficient filling may easily lead to poor forming defects, while excessive filling may lead to a steeper density gradient of the pattern.

②Control the steam heating state. Steam is used as the thermal energy medium for foam mold heating. When superheated steam is used for bead foaming forming, steam enters the mold cavity through the air plug hole in the air chamber. In this way, the beads in the air plug area rapidly expand, overheated, or stuck together, preventing steam from further spreading inward and leading to poor bead fusion inside the cavity. Moist steam will turn into plenty of condensed water on the surface of the beads, and will also prevent the beads from fusing with each other. Therefore, slightly superheated steam is recommended and penetrates into the beads in a relatively dry state.

③Steam should be introduced in due time so that the beads in the mold can fully expand and fuse together. If the time is too long, the mold will shrink during cooling.

④Cool immediately after pattern forming. At the beginning of cooling, the mold wall in contact with the pattern is rapidly and evenly cooled to a certain temperature, and the pattern is also cooled accordingly and strengthened when lower than the glass transition temperature. Due to the poor thermal conductivity of the foam pattern, only the surface of the pattern cools and hardens. The internal expansion pressure of the still hot pattern is applied on a hard shell of the surface. As the surface temperature of the pattern drops, the expansion pressure decreases rapidly, and demolding cannot be started until the pattern is enough stable. If the temperature inside the pattern is not low enough before demolding, the expansion force inside the pattern will cause pattern expansion and demolding.

3. Some requirements for foam forming process

For many manufacturers, due to the lack of reasonable planning for equipment installation in the early stage, the steam tank is far away from the pre-foaming machine and the forming machine, and the steam pipe insulation measures are not properly taken. During the later pre-foaming process, excessive condensed water in steam results in uneven size of the pre-foamed beads, serious caking, and huge waste. Therefore, it is recommended to install a steam separator at the pipe inlet of the pre-foaming machine.
After company visits in the past few years, it was also found that although many companies have installed steam separators, many of them are just decorations. The main problems are as follows: installed drain valves are not automatic or maintained, resulting in that the steam separators do not work continuously; some manufacturers use manual valves for drainage, and the operators only drain water once before work, which not only causes a waste of huge amounts of steam, but also the steam pipe contains a large amount of condensed water during the production process, which seriously affects the normal production of the pre-foaming process.

A similar situation occurs in the foaming forming process. Generally, it is recommended to install an automatic drainage device at the end of the steam pipe and conduct regular maintenance; in addition, water droplets attached to the surface of the mold cavity also seriously affect the filling of the foam beads, affecting the surface smoothness (flatness) of the foam model.

It is recommended that in the actual production process, the mold should have a better water cooling system. The spray pipe water cooling method designed by most mold manufacturers has a good cooling effect on foam forming with more complex structures and higher density. Therefore, it is recommended to customize molds at some more professional manufacturers. Finally, it is important to set reasonable forming parameters. Most manufacturers now use semi-automatic forming machines produced by domestic manufacturers. To produce high-quality foam patterns with high quality and quantity, it is crucial to reasonably optimize the forming parameters.

Regarding the filling method (filling by automatic feed gun and filling by manual feed gun), the position of the feeding port is very important. Mold design should carefully consider how to ensure that the filling resistance of foam beads in the mold cavity is minimal. So once again, it is recommended to choose professional manufacturers.

4. Foam forming process

(1) Mold preheating

Preheating the mold before feeding is to reduce condensed water during bead foam forming and shorten the foam forming time; mold preheating temperature: 50~70°C (preheating methods reasonably selected according to different seasons). Residual water in the mold must be dried before filling to avoid pattern surface defects.

(2) Precautions for filling

①When large beads (specific gravity < 18g/L) are used, a gap smaller than the radius of the pre-foamed beads is often left at the mold parting face to facilitate bead filling; when feed tanks or beads with a specific gravity ≥ 18g/L are used, it is generally not recommended to lift the mold for feeding.

②When feed tanks are used for feeding, too many beads should not be poured into the feed tank (generally about 2/3 of the total volume of the feed tank).

③When a feed tank is used, the pressure of the feed tank is generally about 0.18Mpa (sometimes to be reasonably adjusted according to the structure of the mold and the thickness of the pattern).

④When Vento gun is used, attention should be paid to the intake of compressed air to avoid insufficient filling.

(3) Control of thermoforming parameters

①The forming process should be reasonably selected according to the thickness of different patterns and the density of beads. The forming process should meet the following requirements: keep internal fusion not dense and extend the penetration time; keep the surface fusion not dense and extend the thermal insulation time.

②Under the premise of ensuring the quality of the patterns, low pressure, high flow and multiple heating forming methods should be used whenever possible (to reduce the residual volatile matters in the patterns).

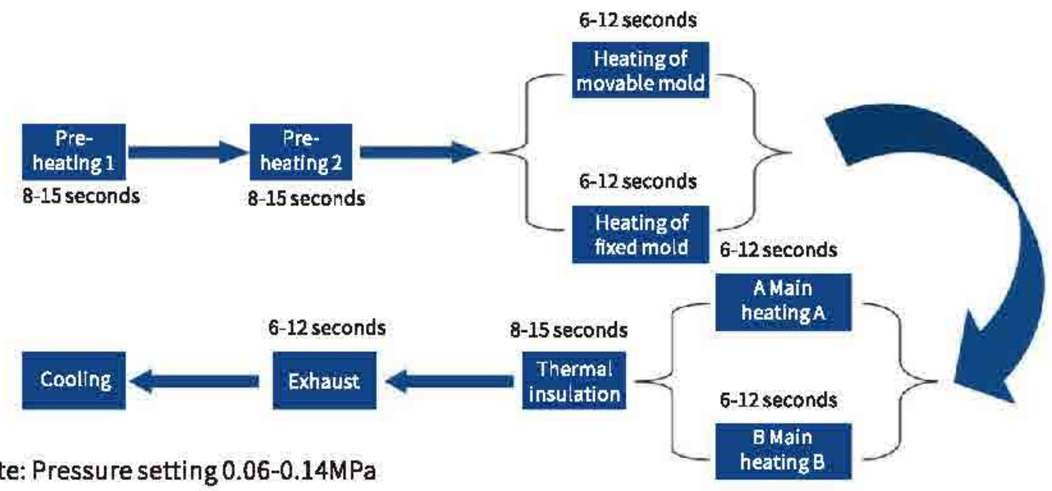
(4) Pattern cooling

① After the inlet valve is closed, water can only be cooled after steam and waste heat in the mold steam chamber have been exhausted. During water cooling, attention should be paid to the water temperature, water pressure and cooling time.

② On the premise of ensuring that the lost foam pattern is qualified, the cooling time and water intake should be reduced whenever possible.

5. Forming process parameters

(1) Press air chamber forming process (see Figure 2.22):



Note: Pressure setting 0.06-0.14MPa

Figure 2.22

(2) Sheet forming process parameters (see Figure 2.23):

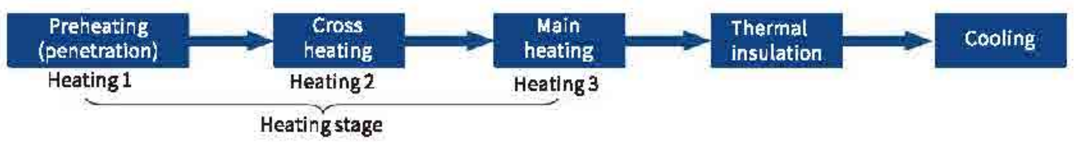


Figure 2.23

Detailed explanation: Operations at the heating stage have a great impact on the quality of the sheet (degree of fusion); generally, the forming process requires several heating processes: heating 1, heating 2, heating 3, etc.

Heating 1: Remaining air between the beads in the mold cavity is replaced by steam, and the beads are softened by steam heating, causing the beads to expand again (parameters: pressure 0.07~0.1MPa, time 60~100 seconds);

Heating 2: The beads are softened through steam heating in layers, and the beads begin to bond slightly (parameters: pressure 0.1~0.12MPa, time 15 seconds);

Heating 3: The real expansion process begins, and the beads are fused together at fusion temperature (parameters: pressure 0.14~0.16MPa, temperature: 110~115℃ + 5℃). Only at this temperature can the beads be better fused.

(3) Quality requirements for high-quality patterns

Optimal raw material distribution within mold cavity during bead filling (avoiding insufficient filling)
Optimal fusion of entire mold during steam filling (avoiding poor fusion and local over-burning)

Optimum density distribution of entire mold (density gradient throughout entire pattern is controlled at $\pm$1g/l).

Best shrinkage rate of entire mold (<0.3% for copolymer patterns; 0.3%~0.8% for EPS patterns).

Dense surface, no gaps between beads (gap between beads on the pattern surface is <0.3mm).

(4) Three states of pattern forming

A. Pattern under normal fusion (see Figure 2.24):
B. Pattern under poor fusion (see Figure 2.25):
C. Melton (over-burned) pattern (see Figure 2.26):

Figure 2.24 Pattern under normal fusion

Figure 2.25 Pattern under poor fusion

Figure 2.26 Melton (over-burned) pattern

(5) Aging of foam pattern

For the current production process in lost foam white area, the two most difficult problems to solve are as follows:

① Density gradient of pattern

Mainly including consistency of pre-foamed beads (uniformity, density fluctuation, and bead quality), filling system and human factors

Ⅱ. Specific embodiments: Uniformity of pre-foamed beads, mold lifting for feeding (generally flat pattern), selection of feeding system, placement of feeding port, size and reasonable distribution of mold air plugs, control of patterns with uneven thickness.

② Control of residual moisture and volatile matter in the pattern mainly includes the loss ratio of volatile content and moisture content.

Specific recommendations:

Ⅰ. Control of volatile content in the pattern:

• Control of volatile matter in original beads: The control of volatile matter should start from original beads (according to the season and use time). The volatile content of STMMA and FD copolymer beads is 9.50%-10.00% and 6.50%-7.50% respectively;

• Control of volatile matters during pre-foaming: 1~2% loss of volatile matters during bead pre-foaming

• Control of volatile matter during bead curing: The loss of volatile matter during the curing process is small (generally <1%). During bead curing, the main purpose is to control the moisture content in the beads.

• Control of volatile matter during forming: 1.5~3% loss of volatile matter during forming

• Control of volatile matter during pattern drying: About 1% loss of volatile matter loss during pattern drying

Ⅱ. Control of moisture content in the pattern:

The residual moisture content in the pattern before casting should be <1% for gray cast iron parts and ductile iron parts, and <0.5% for steel castings, so excess moisture should be quickly and thoroughly removed from the pattern after the foam pattern has been made; most lost foam companies put the formed foam patterns into the drying room immediately (drying for 2 ~5 days). The method to detect whether it is dried is as follows: weigh it on an electronic balance and weigh 3 ~4 times. If the weight change is small, the pattern is considered dry.

Ⅲ. Loss ratio of moisture content: The moisture content of the formed pattern should be reduced by 60% to 70% under natural conditions, and then it is forced to dry in the drying room. In the drying room, the moisture in the pattern is reduced by 20% to 30%.

After the foam pattern is basically dried, the beads on the surface of the pattern are slightly foamed at the drying temperature to lock the surface of the pattern and avoid moisture absorption.

VI. Aging of Foam Patterns

1. Anti-deformation of foam pattern

When the foam pattern is just removed from the mold, the foam pattern becomes the softest at high moisture content and high temperature, and the possibility of the foam pattern deformation is very high. The following two points should be considered during subsequent drying:

(1) For some foam pattern products that are easy to deform, special mold frames should be set up, and their placement method should be carefully considered (see Figure 2.27).

Figure 2.27 Special mold drying rack

(2) During drying and placement, reasonable molds should be used to prevent and correct deformed or easily deformed foam patterns. Otherwise, the late foam pattern has a high scrap rate, and the bonding pressure is high and the efficiency is low (see Figure 2.28).

Figure 2.28

2. Drying control of foam patterns

The drying of foam patterns is generally divided into two parts:

(1) Natural drying: When the foam pattern is just taken out of the mold, it is soft and has high moisture content. In addition, the foaming agent residue in the beads is high. If it is directly delivered to the drying room, the deformation will become serious and tertiary foaming of the beads on the surface of the foam pattern will be required. The tertiary foaming phenomenon of EPS and FD beads is not obvious. The tertiary foaming of STMMA copolymer beads has a slightly greater impact, called "orange peel" phenomenon, which seriously affects the surface quality of castings. The natural drying time is determined based on the product structure, site and tooling conditions. The shortest time is when the water droplets on the surface of the foam pattern are completely evaporated, and the stiffness of the foam pattern is significantly enhanced (generally more than 4 hours) (see Figure 2.29).

Figure 2.29

(2) Forced drying in drying room: the drying temperature is 40~45°C and the humidity is ⩽15%. The foaming agent should evaporate as much as possible, and the drying time is preferably longer than 24 hours. Many problems that arise during later coating and casting are closely related to whether the foam pattern is completely dried. In principle, the longer the foam pattern is placed, the less chance of problem defects, as long as the size shrinkage is ignored.

VII. Bonding of Molds and Clusters

1. Three methods for mold bonding

For some more complex casting products, to facilitate foam pattern forming, the mold is generally designed to be processed in pieces, and multiple molds are bonded together with cold glue or hot glue before sprue bonding.

(1) Manual gluing: Cold glue is manually applied to the parting face of the model, and then the mold is manually closed after a few minutes (see Figure 2.30 and Figure 2.31).

Some products require simple tooling due to their large size and complex structure. This method is relatively simple and practical, and requires low investment. However, the worker's operation level completely depends on "practice makes perfect", and it is difficult to ensure standard operations. Workers' operating skills vary, and glue joints must be treated with repair paste or tape to prevent later paint penetration and slag inclusion.

Figure 2.30 Schematic diagram of manual gluing

Figure 3.34 shows manual gluing, and the joints are treated with tape and newspaper.

Figure 2.31

(2) Gluing by gluing machine: In some of the companies we visited, automatic gluing machines have also been widely used. This machine has been mainly used in leather and shoemaking industries, modified by some companies for mold gluing, and later further designed and improved by professional organizations. In addition, with the successful development of special glue, the automatic glue coating line is uniform and efficient. The glue lines are not additionally processed after mold closing, which simplifies the operation process, improves labor efficiency, facilitates standard operations, and has received the favor of numerous manufacturers (see Figure 2.32 and Figure 2.33).

Figure 2.32

Figure 2.36 shows gluing by gluing machine, and cemented side seams are not treated with tape, newspaper, or repair paste.

Figure 2.33

(3) Hot glue automatic bonding machine: several domestic companies are using automatic bonding machines. For example, a domestic manufacturer produces engine cylinder heads and uses special hot glue as the binder. This operation is highly efficient. It cools quickly after mold closing, and the glue line is not specially treated. However, a special mold should be made (similar to mold opening), which is more expensive, and mold disassembly is more troublesome. It is suitable for large batches of single-variety products (see Figure 2.34).

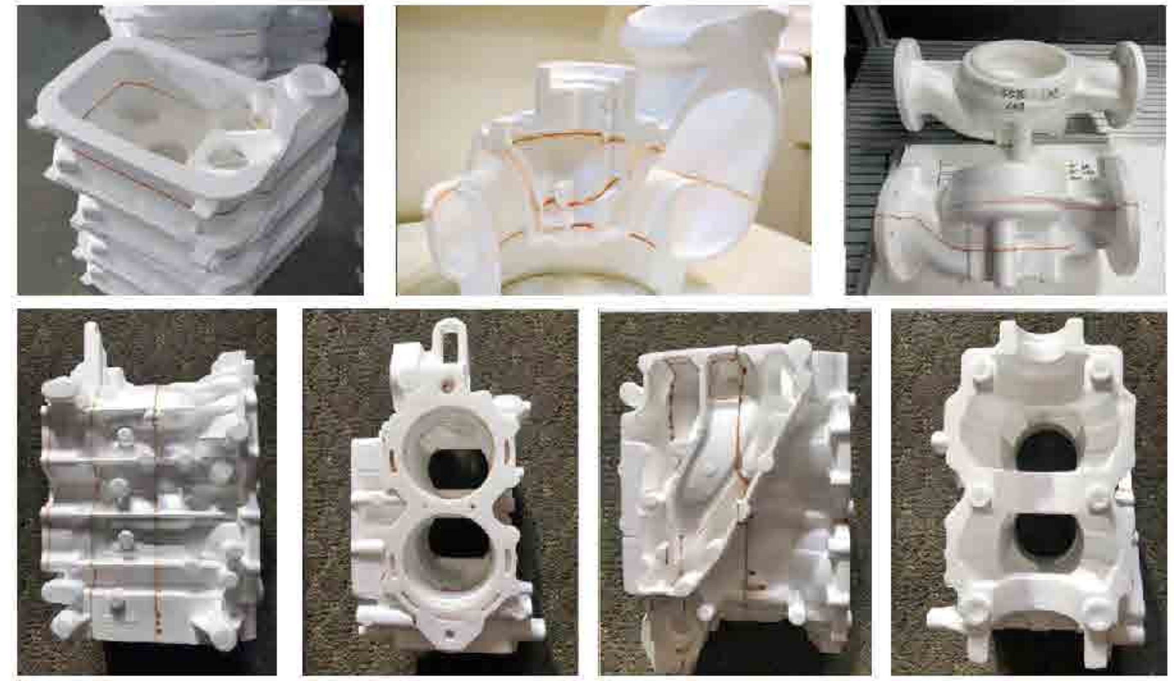


Figure 2.34

The above three operations are currently the more common foam model bonding methods used by domestic companies. Companies can reasonably choose the operation suitable for their own production according to the structure, quantity and on-site conditions of their products.

2. Precautions for mold bonding

In the actual production process, major companies will choose appropriate bonding methods based on existing hardware facilities and product structures. The following issues should be noted in specific operations:

(1) For some thin-walled parts and foam models that are prone to deformation during subsequent operations, corrections should be made before mold closing or tooling, wooden strips (or fiber rods) should be used to prevent deformation. Tooling can be made of aluminum alloy, insulating board and other materials to ensure accuracy.

(2) After the molds are glued, the integrity of the model must be checked. Non-conforming products cannot be sent to subsequent production processes. An automatic gluing machine is used to ensure uniform glue lines, with obvious advantages.

(3) The bonded foam models should be placed on a special formwork and should not be stacked randomly. Before coating, please arrange for special personnel to check and repair to prevent deformation and damage during transportation.

(4) The binder used for bonding foam models should be organic binders. During filling of molten metal, some physical and chemical changes occur, which will cause hidden dangers to the quality of the castings both inside and outside. Therefore, while ensuring the quality of mold bonding, the use of glue should be minimized to reduce the gas evolution rate of the entire model, thereby reducing the chance of defects in the casting.

VIII. Knowledge about Lost Foam Casting White Area

1. Frequently asked questions of bead pre-foaming and solutions

Table 2.5 Frequently Asked Questions of Bead Pre-Foaming and Solutions

Bulk bead coating (powder) during pre-foaming	1. The original bead coating is excessive	Communicate with the bead manufacturer to determine an appropriate coating ratio	1. The coating ratio of small beads is large (≥3‰)
			2. The coating ratio of large beads is small (≤3‰)
	2. The beads and coating are not bonded together well		1. Respond to the bead manufacturer
			2. Manually mix to an appropriate proportion
	3. Beads are sucked, and powder is blown with air	1. Improve the loading mode	Avoid blowing coated powder with compressed air
		2. Install a powder filter	Communicate with equipment manufacturer and then install
The moisture content in pre-foamed beads is large	1. The moisture content in steam is relatively large	Increase the main pipe steam pressure	Main pipe steam pressure ≥ 0.5MPa
		2. Install a steam separator	Keep steam into the pre-foaming machine pipe saturated and slightly superheated
	The pre-foaming barrel has poor thermal insulation effect	Strengthen thermal insulation of the barrel	Keep the maximum and minimum temperatures of the pre-foaming cycle <8°C
	3.The pre-foaming machine is not fully preheated (the upper and lower temperatures of the barrel are inconsistent)	Fully preheat the pre-foaming barrel and keep the upper and lower temperatures of the barrel consistent	Preheating is divided into two steps: 1.Inlet steam preheating; 2.Inlet and exhaust steam cycle preheating
	4. The hot air temperature of the fluidized bed is low or the drying time is short	1. Increase the hot air temperature of the fluidized bed	Control the hot air temperature of the fluidized bed at 30-40°C
		2. Extend the fluidized bed drying time	The recommended fluidized bed drying time is 5-10 minutes
	5. Too high pre-foaming pressure and temperature cause damage to the beads	Reduce the pre-foaming pressure	Steam pressure reference of pre-foaming barrel: 0.03-0.06MP for copolymers; no pressure for EPS materials
		2. Reduce the pre-foaming temperature	Reference of temperature in pre-foaming barrel: 95-105°C for copolymers, 80-95°C for EPS materials
	6. The density of pre-foamed beads is too low	Shorten the pre-foaming time and increase the pre-foaming density	1. Pre-foaming time reference: 35-60 seconds for copolymers; 12-30 seconds for EPS materials
			2. Control the pattern density at 18-26g/l according to forming requirements

Agglomeration of pre-foamed beads	1. The original bead lubricant coating is lacked	Communicate with the bead manufacturer to determine an appropriate coating ratio	1. The coating ratio of small beads is large
			2. The coating ratio of large beads is small
	2. The pre-foaming pressure and temperature are too high and the time is too long	1. Reduce the pre-foaming pressure	Steam pressure reference of pre-foaming barrel: 0.03-0.06MP for copolymers; no pressure for EPS materials
		2. Reduce the pre-foaming temperature	Reference of temperature in pre-foaming barrel: 95-105°C for copolymers, 80-95°C for EPS materials
		3. Shorten the pre-foaming time	Pre-foaming time reference: 35-60 seconds for copolymers; 12-30 seconds for EPS materials
	3. The density of pre-foamed beads is too low	Shorten the pre-foaming time and increase the pre-foaming density	1. Pre-foaming time reference: 35-60seconds for copolymers; 12-30 seconds for EPS materials
			2. Control the pattern density at 18-26g/l according to forming requirements
	4. The moisture content in steam is high	1. Increase main pipe steam pressure	Main pipe steam pressure ≥0.5MPa
		2. Install a steam separator	Keep steam into the pre-foaming machine pipe saturated and slightly superheated
	5. The beads pre-foamed each time are not clean (beads are pre-foamed multiple times)	1. Extend the discharging time	The recommended discharging time is 8-12 seconds
		2. Check equipment operation and damage	Regularly maintain and repair the equipment
The surface of pre-foamed beads is rough(the beads are damaged)	1. The pre-foaming pressure and temperature are too high and the time is too long	1. Reduce the pre-foaming pressure	Steam pressure reference of pre-foaming barrel: 0.03-0.06MP for copolymers; no pressure for EPS materials
		2. Reduce the pre-foaming temperature	Reference of temperature in pre-foaming barrel :95-105°C for copolymers, 80-95°C for EPS materials
		3. Shorten the pre-foaming time	Pre-foaming time reference: 35-60 seconds for copolymers; 12-30 seconds for EPS materials
	2. The beads pre-foamed each time are not clean (beads are pre-foamed multiple times)	1. Extend the discharging time	The recommended discharging time is 8-12 seconds
		2. Check equipment operation and damage	Regularly maintain and repair the equipment
	3. The density of pre-foamed beads is too low	Shorten the pre-foaming time and increase the pre-foaming density	1. Pre-foaming time reference: 35-60 seconds for copolymers; 12-30 seconds for EPS materials
			2. Control the pattern density at 18-26g/l according to forming requirements
	4. Original beads are not aged	Original beads are aged	Spread original beads and place them at 20-35°C and humidity of <30% for 20-30 hours

Pre-foamed beads are uneven

- 1. The feeding amount for each pre-foaming is excessive
  - The feeding amount for pre-foaming should be appropriate
    - Taking 450 pre-foaming machine as an example: feeding amount for each pre-foaming 1,000ml (0.5-0.6kg)
- 2. The pre-foaming machine is not fully preheated (the upper and lower tempe ratures of the barrel are inconsistent)
  - Fully preheat the pre-foaming barrel and keep the upper and lower temperatures of the barrel consistent
    - Preheating is divided into two steps: 1. Inlet steam preheating; 2. Inlet and exhaust steam cycle preheating
- The scraper in the pre-foaming barrel is damaged
  - Replace the damaged scraper
    - Regularly maintain and repair the equipment
- 4. Steam pressure is unstable
  - Keep steam pressure stable
    - 1. Install a surge tank
    - 2. Use separate steam pipes(pipelines)
    - 3. The pipeline design is more reasonable (with pressure reduction and pressure regulation for final control and stabilization)
- 5. The beads pre-foamed each time are not clean (beads arepre-foamed multiple times)
  - 1. Extend the discharging time
    - The recommended discharging time is 8-12 seconds
  - 2. Check equipment operation and damage
    - Regularly maintain and repair the equipment
- 6. The size of original beads is large
  - Reduce the size of beads to 0.15mm
    - 1. Communicate with the bead manufacturer and screen beads
    - 2. Screen pre-foamed beads

High static electricity from pre-foamed beads

- 1. The original bead antistatic coating is lacked
  - Communicate with the bead manufacturer to determine an appropriate coating ratio
    - Apply additional anti-static coating on original beads
- 2. The fluidized bed is blown for too long time
  - Shorten the fluidized bed drying time
    - The recommended fluidized bed drying time is 5-10 minutes
- 3. The foaming time is too long
  - Shorten the pre-foaming time
    - Pre-foaming time reference: 35-60 seconds for copolymers; 12-30 seconds for EPS materials
- 4. There is no static elimination device in bead conveying pipe
  - 1. Install a static elimination device
    - Ground through static conductor (metal wire or object)
  - 2. Replace the foam bead conveying pipe
    - Replace plastic pipes with metal pipes (stainless steel pipes)

The density of pre-foamed beads flu ctuates greatly

- The feeding amount for each pre-foaming is inconsistent
  - The feeding amount for each pre-foaming should be appropriate
    - Taking 450 pre-foaming machine as an example: feeding amount for each pre-foaming 1,000ml (0.5-0.6kg)
- The pre-foaming machine is not fully preheated (the upper and lower temperatures of the barrel are inconsistent)
  - Fully preheat the pre-foaming barrel and keep the upper and lower temperatures of the barrel consistent
    - Preheating is divided into two steps: 1. Inlet steam preheating; 2. Inlet and exhaust steam cycle preheating
- 3. Steam pressure is unstable
  - Keep steam pressure stable
    - 1. Install a surge tank
    - 2. Use separate steam pipes (pipelines)
    - 3. The pipeline design is more reasonable (with pressure reduction and pressure regulation for final control and stabilization)
- 4. Pre-foaming pressure is too high and time is too short
  - 1. Reduce the pre-foaming steam pressure
    - Steam pressure reference of pre-foaming barrel: 0.03-0.06MP for copolymers; no pressure for EPS materials
  - 2. Properly extend the pre-foaming time
    - Pre-foaming time reference: 35-60 seconds for copolymers; 12-30 seconds for EPS materials
- Communicate with the bead manufacturer to determine the foaming agent content of this batch of beads
  - Observe the temperature changes during different pre-foaming periods
    - Reasonably adjust the pre-foaming parameters (especially the temperature changes in whole pre-foaming process) according to temperature changes
- 6. Different batches of beads have different foaming agent contents.
  - Communicate with the bead manufacturer to determine the foaming agent content of this batch of beads
    - Reasonably adjust the pre-foaming parameters according to the different content of bead foaming agent

Poor foaming of foam beads

- 1. The original bead foaming a gent content is low (expired)
  - Forcibly scrapped
    - Ensure the foaming agent content of the original beads: ≥9% for copolymers; ≥6% for EPS
- 2. Low steam pressure and high moisture content
  - 1. Increase main pipe steam pressure
    - Main pipe steam pressure ≥0.5MPa
  - 2. Install a steam separator
    - Keep steam into the pre-foaming machine pipe saturated and slightly superheated
- The pre-foaming machine cannot pressurize and foam
  - Communicate with equipment manufacturers and make adjustment
    - Steam pressure reference of pre-foaming barrel: 0.03-0.06MP for copolymers; no pressure for EPS materials
- 4. The foaming ratio of beads is low
  - Communicate with the bead manufacturer to determine the foaming ratio of this batch of beads
    - Ensure that the foaming ratio of beads is ≥40 times
- 5. The moisture content in original beads is high
  - Communicate with the bead manufacturer and dry the beads
    - Ensure the moisture content in beads is <1% before pre-foaming

2.Common defects of foam patterns and countermeasures

Common defects of foam patterns and countermeasures include 12 major problems that frequently occur in pre-foaming of beads in the lost foam casting white area are as follows:

Table 2.6 Common Defects of Foam Patterns and Countermeasures

Normal pattern appearance but poor internal fusion	1. The heating time is short or the steam pressure is low, and the forming temperature is low	Increase the heating steam pressure and the forming temperature, and extend the foam forming time	1. Forming pressure setting: 0.06-0.14MPa
			2. Forming temperature reference: 105-115℃
			3. Keep internal fusion not dense, and extend the penet ration time
	2. The pre-foamed beads are dry, the curing temperature is high or the time is too long, and the foaming agent content is not enough.	Control the bead drying and curing temperature and time, adjust and control the foaming agent content	1. Recommended aging time for beads: ≥24 hours for copolymers; 4-48 hours for EPS beads
			2. Control of foaming agent content of foam beads before foaming: ≥7% fo r copolymers; ≥4.5% for EPS
Incomplete appearance and unclear profile	1. The mold cavity is not completely filled with beads	Improve the filling method and adjust the compressed air pressure	1. Change suction filling into pressure feeding; when the bead density is <18g/1, choose mold lifting for filling
			2. Control the pressure of the surge tank at 0.14-0.2MPa
	2. The air plug (vent) arrange ment of the mold, the position of the feeding port, and the mold structure are unreasonable.	Improve the mold structure, adjust the arrangement and number of air plugs (vents) and the position of the feeding port	1. Communicate with the mold manufacturer and make changes according to the actual situation
			2. Before the process is determined, trial produce the mold and finalize the plan
	3. The size of the beads is inappropriate	For thin-walled patterns, smaller beads should be selected	Relationship between thinnest wall thickness of model and bead size: 1/9
Internal fusion relaxation and poor fusion in most areas	1. Filling of beads is uneven	Improve filling methods and conditions	Change suction filling into pressure feeding
			2. When the bead density is <18g/1, choose mold lifting for filling
	2. The forming temperature is low and the time is short	Increase the heating steam pressure and extend the heating time	Keep internal fusion not dense, and extend the penetration time
	3. Bead density is too low or foaming agent content is low	Control the pre-foamed bead density and foaming agent content	1. Control the pre-foaming density at 18-26g/l according to different requirements
			2. Control of foaming agent content of foam beads before foaming: ≥7% for copolymers; ≥4.5% for EPS
Large-area shrinkage of pattern	1. The foaming time is toolong or the temperature is too high	Shorten the forming time or reduce the forming temperature	1. Control the main heating time (6-12 seconds); control the holding time (8-15 seconds)
			2. Forming temperature reference: 105-115℃
	2. The cooling speed is too fast (the cooling water temperature is toolow), the cooling time is too long, and the demolding temperature is too low	Adjust cooling speed and time	According to seasonal changes and cooling water temperatures, reasonably control the cooling speed and time (longer in summer, shorter in winter)
Local shrinkage of pattern	Filling is uneven	Ensure even filling	Pay attention to the fluidity of the beads during filling (whether the beads are agglomerated and static)
	2. Heating or cooling is not uniform	Adjust heating and cooling conditions to ensure uniform heating and cooling	1. Avoid steam inlet directly against mold air plug
			2. If the mold steam chamber has a large space or a complex structure, the spray cooling method should be used
	3. The mold structure is unreasonable, and the layout, number or hole diameter of local air plugs (vents) are unreasonable	Improve the mold structure and adjust the position, quantity and hole size of the air plugs (vents)	Communicate with mold manufacturers, and make adjustments and changes
	4. During steam cylinder or whole box foaming, the mold is placed improperly in the steam cylinder or the whole box, facing the steam inlet.	Adjust the position of the mold in the steam cylinder or steam box, and improve the position of the steam inlet pipe or the steam ventilation method of the steam cylinder	During steam penetrate, steam can be dispersed in the steam cylinder or steam box, not in a fixed direction
The size of the model increases, expansion and deformation occur.	The mold is not cooled sufficiently and the demolding time is too early	1. Fully cool the mold so that the mold temperatureis lower than 50℃	Reduce the mold cooling speed and extend the cooling time
		2. Adjust the demolding time	Only after the pattern is fully set can it be demolded
The surface of the pattern is rough and depressions are found at the bead interface	1. The density of beads is too low or the beads are not fully cured	Increase the pre-foaming density of beads and use cured beads	1. Control the pre-foaming density of beads at 18-26g/l according to the subsequent pattern forming requirements
			2. Cure the beads depending on the environment, and maintain an ideal bead aging environment
	The foam forming time is not	Extend the forming time	Keep surface fusion not dense and extend the holding time (8-15 seconds)
	3. The foaming agent content of the beads is low	Increase the foaming agent content of pre-foamed beads	Ensure the foaming agent content of the original beads: ≥9% for copolymers; ≥6% for EPS
	4. The size of the beads is too large	Choose the appropriate bead size	Relationship between thinnest wall thickness of model and bead size: 1/9

The surface of the pattern is uneven and there are protrusions at the bead interface.	1. The forming time is too long	Shorten the forming time	Adopt the forming method with low pressure and multiple pressure relief
	2. The pattern cooling speed is too fast and the cooling time is not enough	Reduce the cooling speed of the mold and extend the cooling time to fully set the pattern	Reasonably adjust the cooling of the pattern according to season and cooling water temperature
The pattern shrinks and deforms after it is just demolded	1. The density of pre-foamed beads is too low	Shorten the pre-foaming time and increase the pre-foaming density	Control the pattern density at 18-26g/l according to forming requirements
	2. The curing time of pre-foamed beads is not enough	Appropriately extend the curing time of pre-foamed beads	The beads are not cured well, the moisture content in the beads in the filling mold is relatively large, and the re-expansion ability of the beads is poor
The moisture content in the pattern is too high	1. Foamed beads are poorly fused	Adjust the heating steam pressure and forming temperature more appropriately	Pay attention to the preheating of the mold before filling (preheating temperature ≥70°C)
	2. Cooling water pressure is too high and time is too long	Adjust cooling water pressure and cooling time	During forming and cooling, cooling water generally does not generate pressure (cooling under normal water pressure)
	3. The forming and heating time is long, and the bead cells may be broken or merged	Shorten the forming and heating time	The heating time of each forming process is generally controlled within 6-12 seconds
	4. The density of pre-foamed beads is too low	Increase the density of pre-foamed beads	According to different bead sizes, reasonably control the pre-foaming density and keep the pre-foaming density not lower than 18g/l
Pattern melting (over-burning)	Heating steam pressure is too high	Reduce the heating steam pressure	Forming pressure setting: 0.06-0.14MPa
	2. The foam forming time is too long	Shorten the heating time	Control the main heating time: 6-12 seconds
	3. There are too many air plugs (vent holes) in the mold or the hole diameter is too large	Adjust the number and hole diameter of air plugs (vents)	Reasonably use quincunx air plugs, strip air plugs or pinhole air plugs according to different mold structures
The pattern is damaged and deformed when it is taken out of the mold	1. The pattern and the mold are bonded together	Regularly lubricate the working surface of the mold	Heat the mold and apply release agent to the mold cavity
	2. The mold structure is unreasonable and the inner wall surface of the mold cavity is rough	Change the mold structure and increase surface finish and draft angle	Communicate with themold manufacturer and make adjustments and changes according to the actual situation