



**Kailin Foundry
Material**

Application of Kailin Ceramic Foundry Sand in Shell Method Castings

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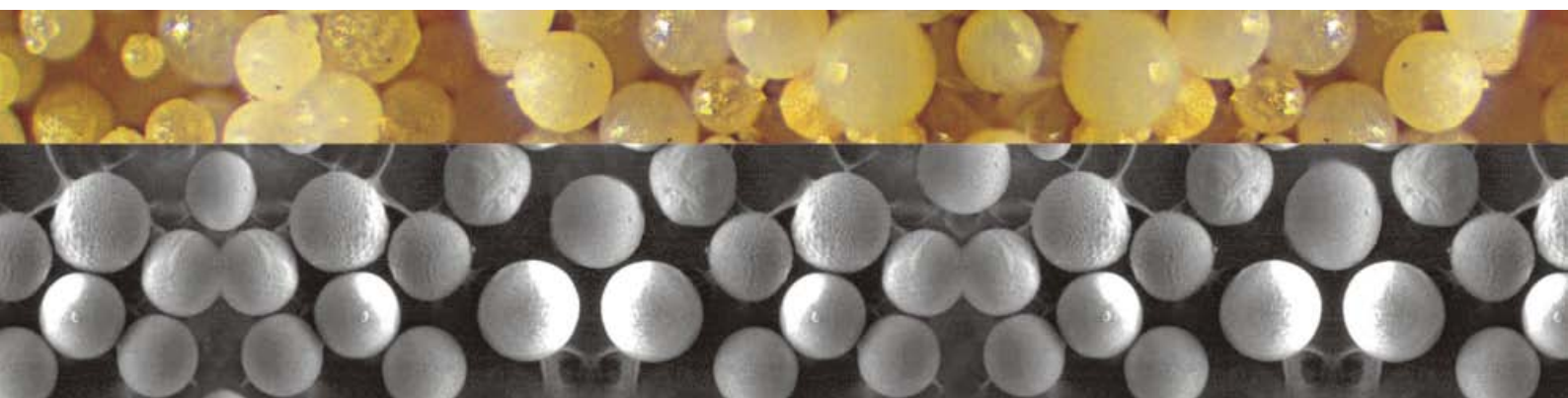
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Contents

Abstract	3
1. Introduction	3
2. Application of Kailin Ceramic Foundry Sand in Shell Mold Technology	4
1. Brief instruction	4
2. The application of Kailin Ceramic Foundry Sand for shell method	6
3. The comparison between Kailin Ceramic Foundry Sand shell process and traditional investment casting process	8
1. The comparison of production process	8
2. The comparison of casting quality	8
3. Cost Analysis	9
4. Technical analysis of Kailin Ceramic Foundry Sand in shell method investment casting process	10
1. Particle size distribution of resin coated sand	10
2. The amount of resin addition	10
3. The process of reclamation	11
5. Conclusion	12
Reference:	12

Kailin Ceramic Sand

Application of Kailin Ceramic Foundry Sand in Shell Method Castings

Abstract

The shell method has a history of several decades, mainly used in cast iron, non-ferrous alloy casting. In recent years, with the rapid promotion of Kailin Ceramic Foundry Sand in the application of resin coated sand, the Kailin Ceramic Foundry Sand for shell method has been extended quickly. Because of the properties of spherical particle shape, high refractoriness, chemically neutral stability, high particle hardness and reclaim yield, the shell method using Kailin Ceramic Foundry Sand is widely used in cast iron, cast steel (including stainless steel), casting alloy etc. It can partially replace lost wax investment casting process, and the casting dimension tolerance can reach CT6-CT7 of standard GB 6414, the surface roughness Ra12.5 or below. This new method can significantly improve casting productivity and quality, greatly reduce casting cost and reduce casting waste emission. In addition, the key point of shell method using Kailin Ceramic Foundry Sand is casting process design and the technology of used sand reclamation. This article mainly introduces some latest application examples and experiences.

1. Introduction

The shell mold casting technology, also called Croning method, was invented by Dr. J. Croning in 1943 at Germany, and it is a method of making the core by heating and curing the molding sand with phenolic resin instantly. In 1944, it began to be used in German foundries, and then, this casting technology was rapidly popularized from 1947 and many enterprises in some countries began to widely adopt and develop shell mold casting method. Furthermore, this method could lead to good finish and accurate dimension, reduce or eliminate machining, shorten the production cycle, save metal materials and reduce the overall cost. Moreover, the casting mold can be made by automatic machinery instead of skilled workers. It is a mature special casting process which is especially suitable for the batch and mass production of small and medium-sized castings of various metals.

In recent years, the development and application of Kailin Ceramic Coated Sand have been rapidly expanded in the scope of shell process. And the main benefits are:

1. Kailin Ceramic Coated Sand can reduce the resin consumption (30%-50%) and gas evolution, improve the strength and toughness of the cast and core sand flowability.
2. Kailin Ceramic Foundry Sand has the property of neutral (PH 7.3) and high refractoriness ($\geq 1800^{\circ}\text{C}$), which is suitable for cast iron, cast steel (carbon steel, medium and low alloy steel, stainless steel, chromium steel, manganese steel) and non-ferrous alloy castings.
3. The particle of Kailin Ceramic Foundry Sand has the property of high hardness, high strength, low crushing rate, high reclaim rate and less waste emissions.

4. Low thermal expansion of Kailin Ceramic Foundry Sand can significantly reduce the tendency of veins in casting.
5. As artificial sand, Kailin Ceramic Foundry Sand has a wide distribution of grain size, which is suitable for all kinds of casting craft and casting craft requirements. It still has higher air permeability even the fine Kailin Ceramic Foundry Sand can be used, and which is beneficial to improve the surface quality of castings.

2. Application of Kailin Ceramic Foundry Sand in Shell Mold Technology

1. Brief instruction

Kailin Ceramic Foundry Sand is new high quality foundry sand developed by Luoyang Kailin foundry material Co. Ltd. in 1999. The main chemical compositions of Kailin Ceramic Foundry Sand are Al_2O_3 and SiO_2 , and the main mineral phases are corundum and mullite.

The chemical composition of Kailin Ceramic Foundry Sand used in casting steel is shown in table 1:

Table 1 Chemical composition of ceramic sand for cast steel

Al_2O_3	SiO_2	TiO_2	Fe_2O_3	K_2O+Na_2O
$\geq 75\%$	15~22%	$\leq 4\%$	$\leq 3\%$	$\leq 1\%$

The table 2 shows the physical and chemical properties of some commonly used coated sand. There are wide range of applications for these raw sand in the coated sand filed as a single main material or add to each other, but the Kailin Ceramic Foundry Sand will be the best choice because by comprehensive consideration, it has better grain shape, the lower consumption of resin, price of the sand, more types of alloy suitable for raw sand, higher rate of reclaim and reuse.

According to the research by Dr. Long Wenyuan from Nanchang Hangkong University, the picture 1 shows the comparison of property of normal and high temperature among silica sand, zircon sand and Kailin Ceramic Foundry Sand.

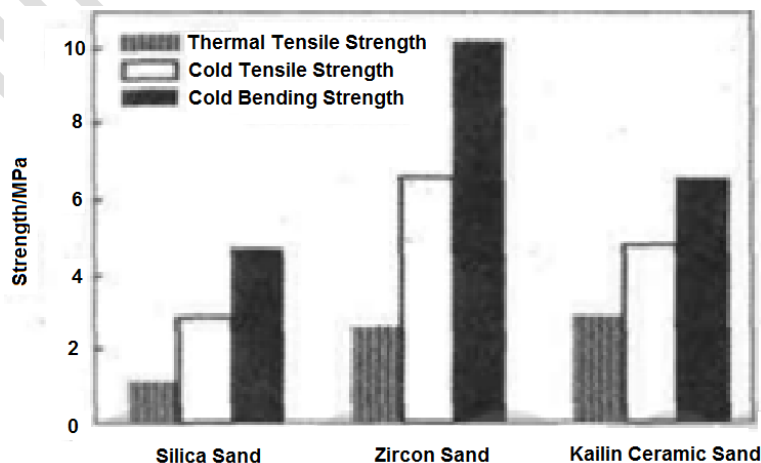


Fig.1 Characteristics of RCS by different base sands

Table 2 Physical and chemical properties of base sand of resin coated sands (typical)

Items	Kailin Ceramic Foundry Sand	Silica Sand	Zircon Sand	Cerabeads
Refractoriness (°C)	1800	1730	1825	1825
Bulk Density (g/cm ³)	2	1.58	2.95	1.69
pH	7.3	6.6	5.7	7.2
Thermal Conductivity(W/m K) (100~ 1000°C)	0.35 ~ 0.50	0.255	0.305	0.223
Lin.exp.coeff. (20~600°C) ×10 ⁻⁶ K ⁻¹	7.2	23	4.1	4.0
Mohs harness	6.5~7.5	6.0~7.0	7.0~8.0	5.0~5.5
Shape	Spherical	Angular	Angular	Spherical

The Kailin Ceramic Foundry Sand with a certain size distribution, after heating and resin coating, is blown and hardened in the hot core box machine to get cores. Then the sand cores are assembled, reinforced, and bonded with gating and rising system. After pouring, the sand cores are basically collapsed, and the finished casting is obtained after cutting, polishing, shot blasting and heat treatment. This process is also called “core-assembling” casting method.

Typical core design and core formation are shown below:



Fig.2 Shell method sand core



Fig.3 Components clutch with gating system after casting

Sand mold (core) is generally designed for multi-cavity, usually double-side cavity. It's better to try to reduce the amount of sand (10mm and below) and reasonable design the clearance of core head when there is an internal sand core. This is not only to ensure the correct positioning and gas evolution, but also to ensure there is no leakage of metal liquid.

Small pin hole (or sand launder) positioning can be set between the upper and lower sand cores, and it can also be

positioned by shape for some simple parts. For the combination of sand cores, the most common practice is to bond sand cores together, put them on the steel plate bracket, fixed clamp the upper pressure plate by pressure, and install the riser to be poured. Meanwhile, try to avoid to using the past common method of filling sand around sand core periphery, filling steel shot and filling dry sand. In addition, some special mounting patterns and tools can be fabricated if there is large batch when necessary.



Fig.4 Cores assembling



Fig.5 Shell method cores assembled to cast

2. The application of Kailin Ceramic Foundry Sand for shell method

The application of Kailin Ceramic Foundry Sand for shell method is developing rapidly in recent years, by using Kailin Ceramic Foundry Sand, many companies have achieved great economic and social benefits from producing construction machinery of bucket tooth, valves, general plumbing parts, hardware, auto parts, and cast iron tools, from the casting areas of iron, carbon steel, non-ferrous alloy, stainless steel, and heat-resistant steel, from the method of sand mold casting, metal mold casting, and investment casting.

In terms of casting technology, Kailin Ceramic Foundry Sand shell method investment casting has been widely used in the following three fields:

- Partial replacement of lost wax investment casting process, specially for some of the relatively simple shaped castings and those needing cores.
- Kailin Ceramic Foundry Sand shell process can replace silica sand shell method to improve the process adaptability so as to extend its application regions.
- Kailin Ceramic Foundry Sand for shell process is adapted where there is a need to improve the quality of casting, reduce the consumption of molding sand and improve the production efficiency of castings.

Here are some sample photos of this application:



Fig.6 Carbon steel castings by ceramic sand shell method Fig.7 Stainless valves and fittings



Fig.8 Stainless balancing kit

Fig.9 Fittings (stainless steel)



Fig.10 Pouring stand of ceramic sand shell method

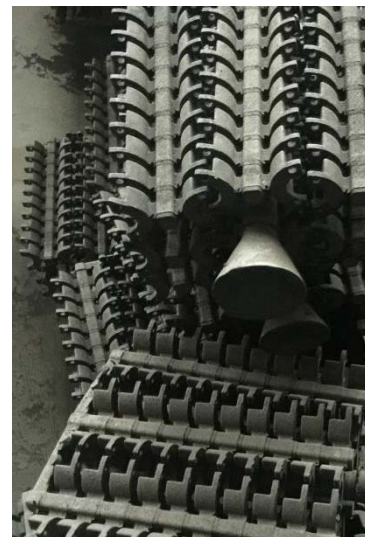


Fig.11 Castings clutches

3. The comparison between Kailin Ceramic Foundry Sand shell process and traditional investment casting process

1. The comparison of production process

Production process comparison of ceramic sand shell method and investment process is showed in Table 3

Table 3 Production process comparison of ceramic sand shell method and investment process

	Investment casting Process	Kailin Ceramic Foundry Sand Shell Method
1	Moulding	Moulding
2	Wax Molding (Injection Wax, Fix Wax, Wax Test)	Core Making (Core Shooting, Deburring, Inspection)
3	Wax patterns assembly	Core Assembling
4	Coating applying	Pouring
5	Shell making and curing	Cuting, Fettle Pouring Gate
6	dewaxing	Shot Blasting Cleaning
7	Mold Shell Baking	Heat Treatment
8	Pouring	
9	Shake-out	
10	Cutting, Fettle Pouring Gate	
11	Shot Blasting	
12	Heat Treatment	

As shown in the above table, compared with traditional investment casting, the production procedures of Kailin Ceramic Foundry Sand shell method are reduced by more than a half. Under the same condition, the production cycle is remarkably reduced. According to production data of some of our customers, the labor cost is reduced by more than 60%.

2. The comparison of casting quality

Kailin Ceramic Foundry Sand shell method, which is based on Kailin Ceramic Foundry Sand as coated sand, generally adopts a finer particle size distribution and reasonable process design, such as selecting and adjusting the metal shrinkage rate. Provided appropriate gating and rising system, proper design of sand core combination form and fit clearance, reasonable design of the core technology, castings with higher quality will be got respectively. According to the actual inspection of one of our customers, the casting dimension accuracy has reached CT6 level of GB/T 6414, and the casting surface roughness has reached Ra12.5 or above, as shown in Figure 12.

In Figure 13, the picture on the right is the casting after first shot blasting (G15 crawler type shot blasting machine). In order to further improve the surface quality, we have tested the casting process of rolling and throwing in the drum, which achieved obvious effects (The packing is AFS 20/30 Kailin Ceramic Foundry Sand),

and the pictures of the castings are showed on the left and middle in Figure 13.



Fig.12 Component by ceramic sand shell method (left) and by investment process (right)



Fig.13 Castings of ceramic sand shell method after drum shot blasting

3. Cost Analysis

Compared with traditional lost wax investment casting process, Kailin Ceramic Foundry Sand shell process has a lower labor cost of over 60% than lost wax investment casting in molding (shell making), dewaxing, film shell roasting, peeling and cleaning.

Although the original cost of Kailin Ceramic Foundry Sand shell process is higher, if the process is equipped with reasonable reclaimed and coating equipment, according to the actual usage of most users, the attrition rate is around 7-8% for each time, the sand can be reused 12-13 times. The reclamation cost is about 70-100 RMB per tonnage, while the resin coating cost of 1 ton sand are approximately 180-200 RMB. To evaluate the overall costs averagely, the total cost of resin coated sand in a single production cycle may be: $(4700+200+13 \times 280) \div 14 = 610$ RMB per ton, where 4700 is the price of Kailin Ceramic Foundry Sand. Assume that the metal-sand ratio is 1:1, 610 RMB per ton can be deemed as the cost of sand to obtain 1 ton of castings.

In addition, by using shell method with Kailin Ceramic Foundry Sand, the production leading time of the two casting processes is 6 days and 3 days respectively, the market response ability is significantly enhanced, the production efficiency is multiplied, and the process yield can be generally increased by more than 30%. According to the statistics of a customer in Zhejiang Province in China, the cost of stainless steel castings produced by them decreased by about 6000 RMB per ton.

Compare with the emission 1-2 tons of solid wastes per ton of castings of lost wax investment casting (mainly the mold shell after pouring), the emission of solid wastes per ton of castings can be reduced to 50-80 Kg by using Kailin Ceramic Foundry Sand shell method investment casting process. The environmental and social benefits are enormous.

4. Technical analysis of Kailin Ceramic Foundry Sand in shell method investment casting process

1. Particle size distribution of resin coated sand

Similar to other resin bonded sand, the grain size of Kailin Ceramic coated Sand will be finer and finer after use. For a certain resin addition, the strength of the coated sand may be decreased, the permeability of coated sand is decreased, but the surface quality of the core and casting are increased accordingly.

At present, more coated sand in China commonly has a particle size of 50/100, 70/140 and 100/200, which mainly depends on the shape of the core, the application situation, and the casting requirements. Kailin Ceramic Foundry Sand shell method, which is used to partially replace the lost wax investment casting process to improve the accuracy and the surface quality of the ordinary sand casting, usually uses 100/200 mesh or finer sand.

The above described sand particle distribution, is gained from experience of using coated quartz sand for decades, so-called general requirements of “five sieve distribution, three sieve relatively concentrated” principle. As a new type of artificial sand, Kailin Ceramic Foundry Sand, which has very different sieving method and physical and chemical properties compared with quartz sand, can be collocated to different particle size distribution as required. Some manufacturers use ϕ -particle size with fine flour (140 mesh and below) to make coated sand to produce high quality castings. The manufacturers of Kailin Ceramic Foundry Sand and foundries should cooperate more closely to explore and test coated sand with more particle size combinations.

2. The amount of resin addition

Because the shape of Kailin Ceramic Foundry Sand is close to spherical, with an angular coefficient less than 1.06. Under the same requirement of strength, the addition of resin can be reduced by 30% compared to quartz sand. According to the research of Dr. Wenyuan Long from Nanchang Aviation University, Kailin Ceramic Foundry Sand can significantly improve the performance of coated sand, its cold specific tensile strength and specific bending strength are up to 3.16 Mpa/1% and 4.35 MPa/1%, and the addition of resin is 1-1.8%.

The following Table 4 is the performance index of two particle size of coated sand:

Table 4 Typical properties of RCS using ceramic sand

	Particle Size	Thermal Tensile Strength (MPa)	Bending Strength (MPa)	LOI(%)	Gas Evolution (ml/g)	Melting Point (°C)
1	50~60AFS	1.8~2.2	6.5~7.5	≤2.5	8~15	110
2	80~110AFS	0.7~1.6	3~3.5	≤2	7~10	100

3. The process of reclamation

According to the statistics and calculation, the consumption is 1.5-2 tons of coated sand (core) for each ton of casting produced by Kailin Ceramic Foundry Sand shell method. In this way, the treatment of the reclamation will be the most critical point of this process. It is not only the need to reduce manufacturing costs and improve economic benefits, but also the need to reduce waste disposal, achieve circular economy, coexist harmoniously with the environment, and achieve sustainable development.

The purpose of reclamation of Kailin Ceramic Coated sand is to remove the residual resin film on the surface of the sand and remove the residual metal and other impurities in the used sand. These residues seriously affect the strength and toughness of re-coated Kailin Ceramic Foundry Sand, while increasing the gas production and the probability of waste products. The quality requirements for reclaimed sand are generally as follows: L.O.I < 0.3% or gas evolution < 0.5ml/g, so the properties of reclaimed sand after coated with this index are not different from that of new sand.

The resin film of Kailin Ceramic Coated Sand, which adopts the binder of novolac phenolic resin, is semi-ductile and can be removed theoretically by both thermal and mechanical methods. And the thermal reclamation is the most sufficient and effective method because of the mechanism of resin film carbonization at high temperature.

As for the thermal reclaim process of Kailin Ceramic Coated Sand, some research institutes and manufacturers have carried out a large number of experimental studies, the result is: calcine temperature in furnace or kiln: 700°C~750°C, sand temperature: 650°C~700°C, and the reclamation process is as follows:

Sand lumpbreaking → metal removal by magnetic device → used sand preheating → bucket elevator → screw feeder → reclaimed sand storage bucket → air-blower → fluidized bed → dust removal system → core sand power → bucket lifter → fumes emission → waste sand conveying → fluidised sand heating furnace → intermediate sand bucket → coated sand production line.

In terms of Kailin Ceramic Foundry Sand reclaim equipment, the thermal reclamation is the common method, the energy is electricity, gas, coal, biomass fuel etc, and the heat exchange has contact and airflow boiling type. In addition to some more mature reclaim equipment making by well-known large companies, many small company built their own reclaim equipment with a lot of ingenuity.

For most small and medium parts foundries, the metal-sand ratio can reach 1:1 or even higher in many cases. After pouring, the core sand is basically heating through, so it is necessary to test mechanical reclamation on this basis to confirm the reclaim effect.

There are two pictures of simple reclaim and coated production lines



Fig.15 Production line of sand reclamation and resin coating(use oil or gas fuel)



Fig.16 A sand reclamation rotary drum (gas fueled)

5. Conclusion

1. Kailin Ceramic Foundry Sand in shell method can be widely used in cast iron, cast carbon steel, cast medium and low alloy steel, stainless steel and non-ferrous alloy coating of different materials
2. Kailin Ceramic Foundry Sand shell method can reach the casting accuracy CT6 - CT7 and the surface roughness can reach Ra12.5 or above. It can greatly improve the quality of sand mould casting and partly replace the lost wax investment casting process.
3. The production efficiency and market reaction speed can be greatly improved by using Kailin Ceramic Foundry Sand shell process
4. The use of Kailin Ceramic Foundry Sand shell process can significantly reduce the cost of the casting and obtain huge economic benefits
5. The used sand reclamation process is simple and convenient, which greatly reduce the emission of solid waste and other pollutants, while obtaining economic benefits and environmental benefits. It is a sustainable development of casting technology

Reference:

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2. Xuezhong Sun, "Used sand reclaim technology for mold casting"[J], 2015 (6)