Kailin Foundry
Material

Application of Kailin Ceramic Foundry Sand in Alkali Phenolic Resin No-bake Process

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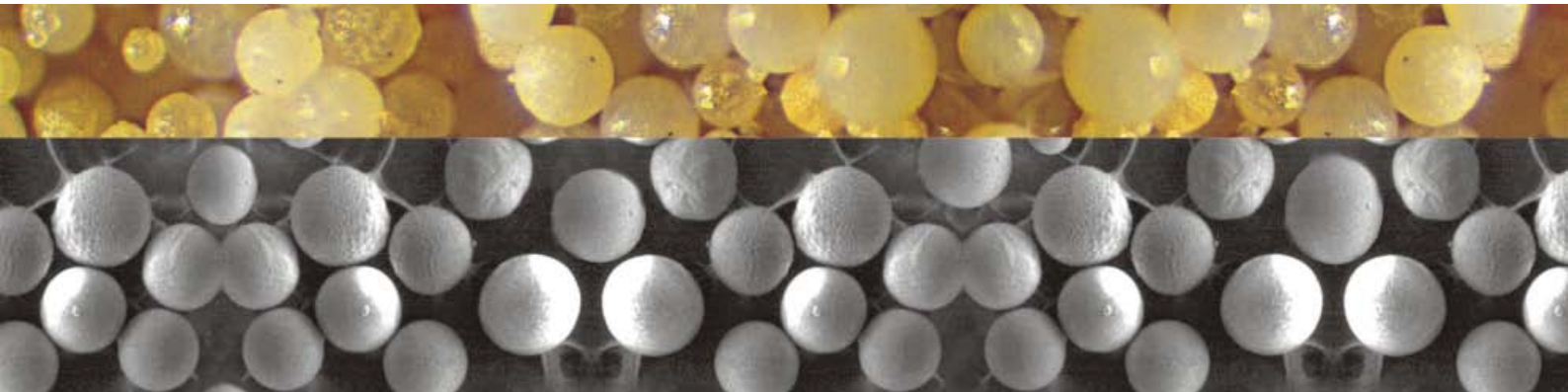

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Contents

Application of Ceramic Sand in Alkaline Phenolic Resin No-bake Process

Abstract

For the production of steel castings, sodium silicate no-bake sand, furan resin no-bake sand and alkali phenolic resin are commonly used. Since the 1990s, the above various molding and core-making processes have been tested (practiced) under various adaptive conditions and have been produced for more than 30 years. With the discovery and popularization of Kailin Ceramic Foundry Sand, and the improvement of used sand recycling technology, Alkaline phenolic resin no-bake sand gradually shows the advantages of high-quality steel castings in mass production, and is increasingly becoming the primary choice of molding process for newly-built and reconstructed cast steel mills.

1. Overview of ester hardened alkaline phenolic resin no-bake sand

The ester-hardened alkaline phenolic resin no-bake sand (α hardening process) was invented by British Borden Company in 1980s. It is a resole phenolic resin formed by the reaction of phenol with excess formaldehyde in an alkaline medium, and the hardener used is mainly organic ester.

Alkaline phenolic resin no-bake process has advantages of general resin boned no-bake sand with good collapsibility, fast hardening speed, and the work time being able to be adjusted within a large range, and:

1. The alkaline phenolic resin binder, which does not contain furfuran alcohol, is synthesized from phenol and formaldehyde, and the hardener is usually a mixture of glycerin acetate. In the pouring and cooling process, there are no nitrogen, phosphorus, sulfur and other elements that can enter the molten steel to affect its quality, so there is basically no defect of sulfurizing and needle-like pores in the surface layer that differ from steel castings produced by furan resin.
2. The free phenol and free aldehyde in the basic phenolic resin are relatively low, and the hardener is a mixture of glycerin acetate. In the process of sand mixing, molding, core making, pouring, and sand cleaning, the toxic and irritating gas is not likely to release, so basically there is no harm to the operating environment.
3. Alkaline phenolic resin is strongly alkalinous, and the requirement of the acid demand value of base sand is not so strict, so alkaline sand can be used. For example, the chromite sand is used in large steel castings in large quantity.

Although the ester hardening alkaline phenolic resin no-bake sand has the above advantages, the process also has some drawbacks, which makes this process to be not as widely used in the Western countries.

The main problems are:

1. The strength of the alkaline phenolic resin is relatively low, so the addition of resin in molding sand is high, which leads to high production cost.
2. The reclamation performance of used sand is not so good. The reclamation yield of furan resin used sand can

generally reach more than 95%, while the used sand reclaimed rate of alkaline phenolic resin can only reach about 70%-80%,wich increases the addition of new sand and the emission of used sand, so alkaline phenolic resin resulted in the cost increasing and environment pollution.

3. Alkaline phenolic resin shelf life is relatively shorter, generally within six months.

In order to fully exploit the advantages of the alkaline phenolic resin process and overcome its shortage, foundry workers, for years of modified resin/hardener system, uses special sand (such as Kailin Ceramic Foundry Sand), improves the used sand reclaimed process and equipment, etc., has obtained the remarkable results, which has enabled this process to produce high quality steel castings efficiently and environmentally with significantly reduced production costs.

2. The characteristics of Kailin Ceramic Foundry Sand & performance of alkaline phenolic Kailin Ceramic Foundry Sand

Kailin Ceramic Foundry Sand is a new type of high quality foundry sand developed by Luoyang Kailin Foundry Material Co. Ltd. in the late 1990s. The main chemical composition of Kailin Ceramic Foundry Sand is are Al_2O_3 and SiO_2, and the main mineral phases are corundum and mullite.

The manufacturing method of Kailin Ceramic Foundry Sand is: The high-quality bauxite raw material is selected and melted in an electric arc furnace. Then the molten liquid is blown off by a compressed air flow when it flows out of the melting device. After cooling, spherical or nearly spherical particles with smooth surface are obtained, and the surface is smooth. The production diagram of Kailin Ceramic Foundry Sand is shown in Figure 1, and the electron microscopic photographs of Kailin Ceramic Foundry Sand are shown in Figure 2 & 3.

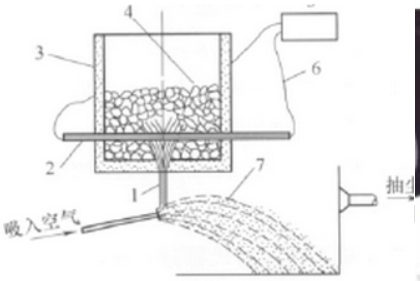


Figure 1 Production diagram

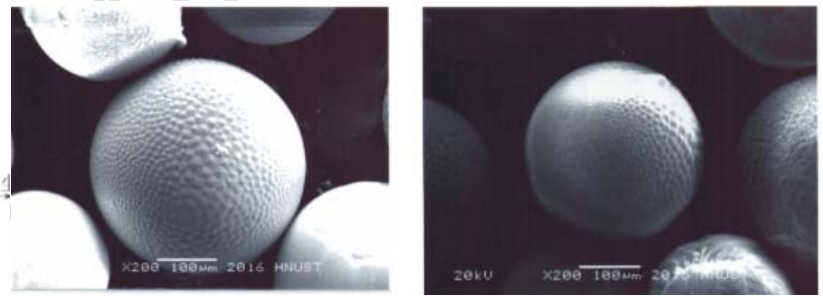
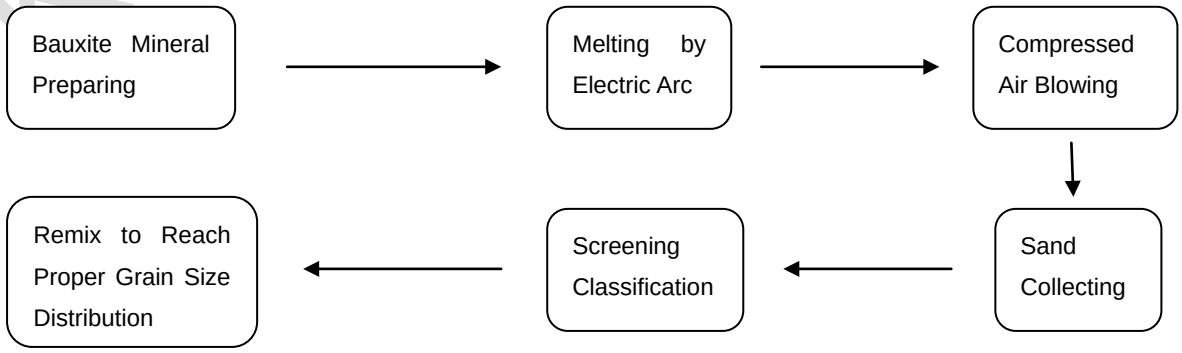


Figure 2 & 3 Electron Microscopic photograph

The production process of Kailin Ceramic Foundry Sand may be described as follows:



The chemical composition of Kailin Ceramic Foundry Sand for cast steel:

Al_2O_3	SiO_2	TiO_2	Fe_2O_3	K_2O+Na_2O
≥73%	**15~22%**	**≤4%**	**≤3%**	**≤1%**

Table 1 Chemical Composition

The main physical and chemical properties of Kailin Ceramic Foundry Sand:

Name	Main composition	Angularity Factor	Bulk Density	Mohs' hardness	Refractoriness	Lin. Exp. Coeff. （20~600℃）	pH
Kailin Ceramic Foundry Sand	Al_2O_3≥73% Fe_2O_3 ≤3%	1.06	2	7.5	≥1800℃	7.2×10^{-6} /K	7.3

Table 2 Chemical & Physical Property

The shape of Kailin Ceramic Foundry Sand is spherical or nearly spherical, and the color is black and brown. The particle size is 0.053-3.36 mm (270 – 6 mesh). Customers can specify the particle size distribution according to their own process requirements.

Due to its superior physical and chemical properties, Kailin Ceramic Foundry Sand has obvious casting performance advantages over silica sand and other special foundry sands:

1. The shape of the particle is spherical and the surface is smooth. Under the same strength requirement, the amount of resin consumption can be 30%-40% less than the using of silica sand, and the amount of gas evolution generated by the mold/core is greatly reduced.
2. Kailin Ceramic Foundry Sand has the properties of high refractoriness and neutral, which can be used with a variety of cast alloys, including stainless steel, manganese steel, chrome steel casting.
3. The performance of good fluidity and easy to fill allows Kailin Ceramic Foundry Sand to be able to make sand cores with very complicated shapes and small cross-sections.
4. Kailin Ceramic Foundry Sand has a low expansion coefficient and reduces casting defects such as veins caused by sand expansion.
5. Kailin Ceramic Foundry Sand has performance of high strength, low crushing rate, high durability and reclaimed yield. The reclaimed yield can reach up to 98%.
6. Kailin Ceramic Foundry Sand has the advantages of high thermal conductivity, excellent gas permeability and good collapsibility after pouring.
7. Kailin Ceramic Foundry Sand has the advantages of environmental protection, which producing less cast waste (waste sand) and less gas evolution. It is known as the green casting material of the 21st century.

   In order to verify the characteristics of Kailin Ceramic Foundry Sand in the application of alkali phenolic resin no-bake process, Luoyang Kailin Foundry Material Co., Ltd, and a steel casting factory in Shandong conducted laboratory experiments. And the results are as follows:

Table 3 Test Results

No.	Name	Ratio	Compressive Strength (MPa)				Tensile Strength (MPa)		Gas Evolution (ml/g)	Sample Avg. Weight(g)
			15min	40min	1h	24h	1h	24h	24h	Compressive Sample
1	Alkali Pheno. Used Sand	Sand 100%+Resin 1.5% (ratio of Sand) +Hardener 20% (Ratio of Resin)	/	0.434	0.547	0.993	/	0.373	30.5, 39.8, 31.5 Avg. 33.9	139
2	Silica New Sand	Sand 100%+Resin 1.5% (Ratio of Sand) +Hardener 20% (Ratio of Resin)	0.113	0.453	0.758	1.17	0.42	0.98	15.5, 14.2, 13.6 Avg. 14.4	145
3	Kailin Cera. Sand (30/70)	Sand 100%+Resin 0.9% (Ratio of Sand) +Hardener 20% (Ratio of Resin)	0.14	0.596	1.058	1.33	/	1.95	10.2, 9.3, 9.9 Avg. 9.8	183
4	Kailin Cera. Sand(40/70)	Sand 100%+Resin 0.9% (Ratio of Sand) +Hardener 20% (Ratio of Resin)	0.185	0.725	0.98	1.25	0.87	1.84	10.1, 9.5, 9.2 Avg. 9.6	189

The analysis of test results:

a. In the case where the addition of the resin is reduced by 40%, the compressive strength in 15 minutes is increased by 24%, the compressive strength in 40 minutes is increased by 31%, and the final compression strength is increased by 39%. Under the same strength condition, the amount of resin added is 45%-50% less.

b. Compared with the new silica sand, the amount of sand gas evolution is reduced by 32%, which is roughly equivalent to the proportion of the addition of the resin.
c. The gas evolution of reclaimed used sand mixture is as high as 33.9ml/g, indicating poor reclaimed rate and more residual resin.
d. According to the weight of the standard sample piece of compression strength test, the weight of Kailin Ceramic Foundry Sand mixture per cubic meter is about 30% heavier than the silica sand mixture.

3. The application of Kailin Ceramic Foundry Sand in alkaline phenolic resin no-bake process

1. The Examples of the application

Under the joint efforts and effective cooperation of Luoyang Kailin Foundry Material company and related foundry manufacturers, in the past ten years, more than ten large and medium-size cast steel mills in China have successfully produced high quality steel casting by using Kailin Ceramic Foundry Sand alkali phenolic no-bake resin sand. Among them, there are new build steel mills, and also there are factories that implement Kailin Ceramic Foundry Sand alkali phenolic no-bake sand technology through technical transformation. Some prominent factories are: Samyoung M-TEK, Dalian DSD (Dalian Samyoung Doosan Metal Product Co.,Ltd), Wuxi KOSO Valve, Anhui Conch Kawasaki Equipment Manufacturing Co, Ltd., Shandong Komatsu Mechanism company, Shantui Steel Casting Co.,Ltd. Etc.

a. Samyoung M-TEK, which purchased 1,200 tons of Kailin Ceramic Foundry Sand one-time, gained an annual output of steel castings of 30,000 tons. Its products are mainly used for casting steel for marine and bridge, the maximum single piece weight is 30 tons, and the material is high alloy cast steel and carbon steel. The particle size of Kailin Ceramic Foundry Sand is AFS 65.
b. Dalian DSD (Dalian Samyoung Doosan Metal Product Co.,Ltd), which was established in July 2005, is a joint venture established by Korea Samyoung M-TEK and Korea Doosan Engine Co., Ltd. The main products are marine diesel engine parts, other ship-specific accessories, mining machinery steel castings, bridges and construction steel castings, and the maximum single piece weight is 20 tons. According to Korea Samyoung M-TEK's plan, the casting process is equipped with 900 tons of Kailin Ceramic Foundry Sand, with an annual output of 12,000 tons and a sand-metal ratio of about 4:1. In addition, the production lined is using Japanese Sinto company's reclamation equipment, and the monthly Kailin Ceramic Foundry Sand compensation is about 3% of the total sand. The replacement cycle of the entire process line of sand in the plant is about three years. According to its annual output and sand consumption, the sand consumption per ton of casting is about 32 kg.
c. Wuxi KOSO Valve, which produces low carbon steel and stainless steel valves, has a maximum casting weight of 2 tons. The products are mainly exported to Japan. The size of Kailin Ceramic Foundry Sand used

Figure 3 Wuxi KOSO Valve using Kailin Ceramic Foundry Sand molding core

is AFS 55. Figure 3 is a picture of the company using the Kailin Ceramic Foundry Sand molding core.

d. Anhui Conch Kawasaki Equipment Manufacturing Co, Ltd. Mainly produces wear-resistant parts, the main materials are stainless steel, manganese steel, high-chromium cast iron etc. The particle size of Kailin Ceramic Foundry Sand is AFS 65.

e. Shandong Komatsu Engine company mainly produces construction machinery and accessories. The castings are made of carbon steel, manganese steel and alloy cast steel. The particle size of Kailin Ceramic Foundry Sand is AFS 65. The Figure 4 is shown below:

Figure 4 Alkaline phenolic resin bonded Kailin Ceramic Foundry Sand molding line in Shandong Province

(P.S.: Due to the technical confidentiality of the company, specific technical parameters cannot be provided)

2. Technical concerns related to the application of Kailin Ceramic Foundry Sand in alkaline phenolic resin no-bake process

a. About the chemical composition of Kailin Ceramic Foundry Sand

The main chemical compositions of Kailin Ceramic Foundry Sand are Al_2O_3 and SiO_2, along with some TiO_2, Fe_2O_3, Na_2O, K_2O etc. In addition, among them, Fe_2O_3, Na_2O, and K_2O significantly reduce the refractoriness, strength and durability of the Kailin Ceramic Foundry Sand, which are the component that needs to be restricted. Furthermore, as the main and most important component of Kailin Ceramic Foundry Sand, The higher Al_2O_3 content, the better the comprehensive performance of Kailin Ceramic Foundry Sand. At the same time, with the increase of Al_2O_3, the above harmful components are also reduced accordingly. According to the practice of various foundries in recent years, Al_2O_3 of Kailin Ceramic Foundry Sand used for the alkaline phenolic resin no-bake process is preferably more than 72%.

b. About the particle size distribution of Kailin Ceramic Foundry Sand.

The 40/50 mesh (AFS 30-40) high silica quartz sand is generally used as silica sand alkali phenolic resin no-bake process in China. Because the quartz sand particles are angular in shape, they have the function of inlaid each other. At the same time, the casting process generally adopts the facing and backing sand process, which can just meet the requirements of both compression strength and surface quality. However, for Kailin Ceramic Foundry Sand, because the grain shape is too round and the surface is too smooth, if the particle size is similar to that of silica sand, it will cause low wet strength or even creep of sand mould. Practice has proved that when using Kailin Ceramic Foundry Sand in the alkali phenolic resin no-bake process, the sand

needs to be a finer particle size and has a wider particle size distribution. It is worth noting that compare normally AFS 40 Kailin Ceramic Foundry Sand being used in iron parts casting, users in countries such as Japan and South Korea often use Kailin Ceramic Foundry Sand with a particle size as fine as AFS 60-70. In conclusion, when using Kailin Ceramic Foundry Sand alkali phenolic resin no-bake process, the raw sand with relatively fine particle size and wide distribution should be used. And also, the particle size distribution should be selected after the test according to the requirements of the specific parts.

c. About the reclaimed technology of Kailin Ceramic Foundry Sand alkali phenolic resin no-bake process.

In addition to the rapid development of alkaline phenolic resin no-bake process in steel casting due to the excellent properties of Kailin Ceramic Foundry Sand, the advancement of used sand reclaimed technology is another key factor in the rapid development of the process. Since the alkaline phenolic resin film is a rigid resin film, the used sand reclamation is very difficult and the recycling efficiency is low compared to the furan resin no-bake sand. The used sand reclamation methods can be roughly summarized as wet method, thermal method and dry method (mechanical method). In addition to mechanical reclamation, there are often two or more combined reclamation methods. Furthermore, people have found in a large number of researches and practical applications that ester hardening alkali phenolic resin sand is no-bake sand that is relatively difficult to reclaim effectively, and its difficulty of reclaim is next to sodium silicate sand, but far more difficult than furan resin sand and Pep-set sand. Meanwhile, the most obvious feature of alkali phenolic resin sand is that the strength of the reclaimed bonded sand mold is getting lower and lower, so that the mold is likely to be broken, collapsed, difficult to mold, or the casting may be washed and stuck with sand, and the defects of the pores are likely to occur. After long-term production practice, mechanical reclamation has gradually dominated. In particular, the pressure attrition reclamation technology of Japanese Sinto Company has an obvious effect and has been applied more and more. All of the companies listed above are using the reclamation equipment of Sinto, which reclaim effect can achieve a L.O.I reduction of about 35% of the used sand burning (L.O.I) reduction per reclaim cycle, and some manufacturers have indicated that the use of Kailin Ceramic Foundry Sand alkali phenolic resin no-bake process after reclaiming by Sinton reclamation equipment can obtain an L.O.I as low as 0.6%. And the improvement of the reclamation yield of Kailin ceramic used sand can reach a yield rate of 98%. The sand reclamation process by Sinto Company is showed in Figure 5 and the used sand reclamation workshop is showed in Figure 6.

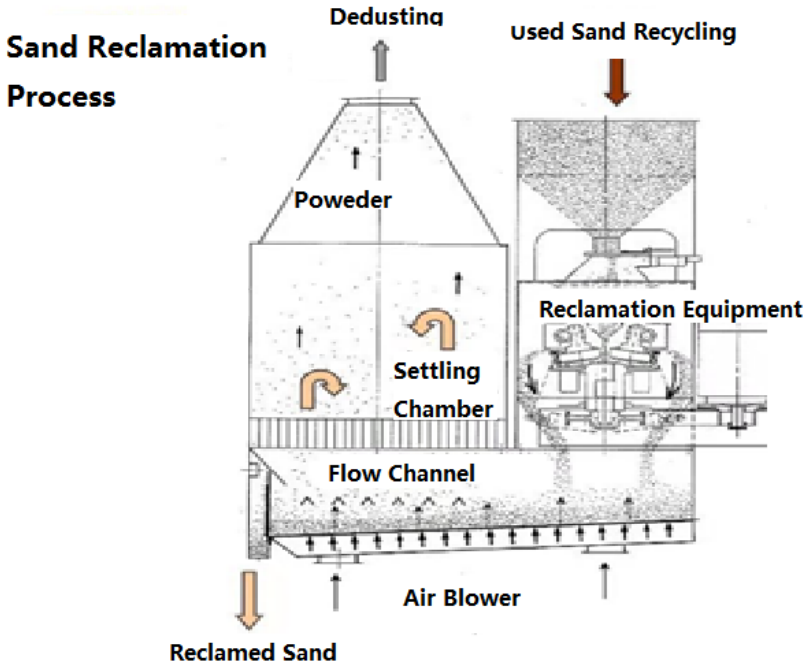


Figure 5 Schematic design of sand reclamation by Sinto Company

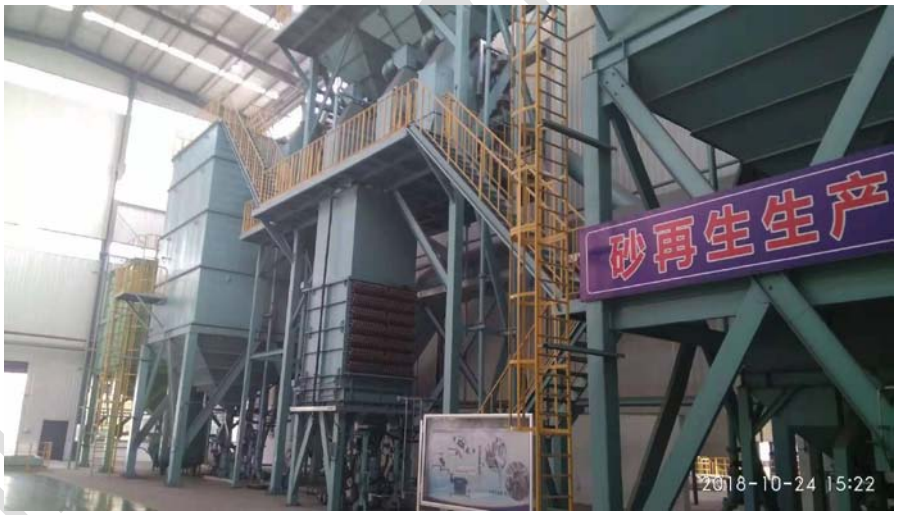


Figure 6 Used sand reclamation workshop

4. Benefit analysis of Kailin Ceramic Foundry Sand in alkaline phenolic resin no-bake process

Material Cost: Kailin Ceramic Foundry Sand

1. According to the current market price and casting process, a famous enterprise in Shanghai calculated the cost of Kailin Ceramic Foundry Sand alkaline phenolic no-bake sand and quartz sand. And the price is Kailin Ceramic Foundry Sand 4900 RMB/ton, silica sand 330RMB/ton, chromites 3200 RMB/ton, phenolic resin 6300 RMB/ton, phenolic resin hardener 12400 RMB/ton, sand-metal ratio: 2.8:1, so the comparison of economic operation

benefits are showed in table 4:

Table 4 Profit comparisons by alkali phenolic resin bonded ceramic sand and silica sand

Type and Unit		Silica Sand	Kailin Ceramic Foundry Sand
Alkaline Phenolic Resin	Unit: RMB/Ton	6300	6300
	Addition	1.9%	1%
	Sand-metal Ratio	2.8:1	(2.8×1.3):1
	Subtotal: RMB/Ton	6300×1.9%×2.8=335	6300×1%×(2.8×1.3)=229
Hardener	Unit: RMB/Ton	12400	12400
	Addition	1.9%×22%	1%×22%
	Sand-metal Ratio	2.8:1	(2.8×1.3):1
	Subtotal: RMB/Ton	12400×1.9%×22%×2.8=145	12400×1%×22%×(2.8×1.3) =99.3
New Sand	Unit: RMB/Ton	330	490
	Addition	20%(Reclaim yield 80%）	3%（Reclaim yield 97%）
	Sand-metal Ratio	2.8:1	(2.8×1.3):1
	Subtotal: RMB/Ton	330×20%×2.8=184.8	4900×3%×2.8×1.3=535.1
Chromite Sand	Unit: RMB/Ton	3200	N/A
	Addition	1.50%	
	Sand-metal Ratio	2.8:1	
	Subtotal: RMB/Ton	3200×1.5%×2.8=134.4	
Coating	Unit: RMB/Ton	82.5（2~3 Times）	50（1~2Times）
Post-Processing	Labor：RMB/Ton	756	529
	Material：RMB/Ton	165	115.5
Waste disposal	Unit: RMB/Ton	289	289
	Subtotal: RMB/Ton	289×10%×2.8=81	289×4%×2.8=32
Total	Total: RMB/Ton	335+145+184.8+134.4+ 82.5+756+165+81=1883.7	229+99.3+535.1+50+529+ 115.5+32=1589.9

P.S.：The bulk density of Silica sand and Kailin Ceramic Foundry Sand is 1:1.3, and the price is without tax

Therefore, according to the above table, the comprehensive cost of steel casting per ton can be saved **293.8 RMB**

2. The use of Kailin Ceramic Foundry Sand molding and core-making can greatly improve the dimensional accuracy of the core, and thereby improve the utilization rate of metal materials, this is one of the important reason that Japanese, South Korean foundries use a large quantity of Kailin Ceramic Foundry Sand. Over the past years, developed countries in Europe and the United States have started to apply Kailin Ceramic Foundry Sand to 3D printing technology, in virtue of its superior performance, can reduce molding cost, improve casting quality and

material utilization.

3. Social benefits
   a. Reduce waste disposal, achieve green manufacturing and apply government subsidies.
   b. Improve working environment, reduce dust in air so as to reduce the risk of encountering silicosis
   c. Adopting universal sand instead of facing and backing sand, which improve the efficiency of molding. Meanwhile, the workload and expense of shake-out, shot-blasting and finishing are significantly reduced, so as to improve work efficiency and reduce labor cost. (Dalian DSD Company reduce 60% cleaning work load by using Kailin Ceramic Foundry Sand)
4. Improve product quality, reduce welding repair rates and expenses, reduce scrap rate and improve casting surface quality.

5. Conclusion

The process of alkali phenolic resin no-bake using Kailin Ceramic Foundry Sand to produce steel castings, provided effective reclamation equipment, can get the benefits and effects as below:

a. The base sand consumption was significantly reduced – 30-50 kgs and to per ton of castings
b. Significantly reduce the addition of binder – reduces by 30-50%
c. Improve the precision of core and material utilization rate
d. Improve particle surface quality, reduce shake-out and finishing workload (by a rate up to 60%)
e. Improve casting quality, reduce casting production and quality cost
f. Reduce the emission of waste gas and sand to achieve green production manufacturing
g. Improve working environment, reduce dust in air and the risk of encountering silicosis.

With the continuous improvement of casting quality requirements, as well as the increasing pressure of production cost and environmental protection cost, it can be predicted that Kailin Ceramic Foundry Sand alkali phenolic resin no-bake process will be widely used to produce high-quality steel castings in a rapid growth period for the next 3-5 years.

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