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(54) SHELL MOLD SINTERING METHOD AND APPARATUS

(57) A shell mold sintering method, comprising the following steps: S1. producing a shell mold, wherein carbon powder needs to be added during a shell mold production process; S2. dewaxing the produced shell mold, and then placing the mold into a sintering apparatus while ensuring that there is adequate oxygen content in a sintering furnace and keeping the temperature in the sintering furnace between 600#-800#, until residual wax in the shell mold is completely burned off; S3. reducing oxygen content in the sintering furnace, and increasing the temperature until a sintering temperature of the shell mold is reached; S4. in said low-oxygen or anaerobic environment, keeping the temperature within the sintering furnace at the sintering temperature of the shell mold, until sintering of the shell mold is completed. A shell mold sintering apparatus, comprising: a shell mold placement platform (1), a heating apparatus (2), an air-blowing apparatus (3), an exhaust flue (4), a control system (5), a sintering chamber (6) and a closure door (7); the control system controls the heating apparatus, the air-blowing apparatus and the exhaust flue on the basis of said shell mold sintering method so as to implement shell mold sintering operations. Using the sintering method and apparatus may improve stability of quality and production efficiency, while reducing production cost.

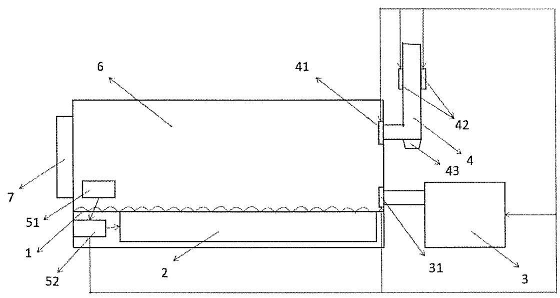

Figure 3

EP 3 357 602 A1

Description

Technical Field

[0001] The present invention relates to precision casting process, particularly to a shell mold sintering method and special apparatus for the same.

Background

[0002] Precision casting is a casting method relative to traditional casting process, capable of obtaining a relatively accurate shape and higher casting precision. The precision casting process is: first, producing a wax mold, having a size and shape consistent with a product to be cast; then forming a ceramic shell on a surface of the produced wax mold; afterwards, dewaxing the ceramic shell (removing the wax mold inside after melting); later, sintering the ceramic shell at a high temperature; finally, pouring a metal material into the sintered ceramic shell, after the metal material is cooled and solidified, crushing to remove the ceramic shell, and the obtained casting is the required product.

[0003] In the above process, production of the ceramic shell is vital, and its quality determines the quality of the casting. At present, the common method of producing a ceramic mold is: shell mold method, specifically water soluble silica sol shell production method, in which, during production of a ceramic shell, a ceramic shell with the required thickness is produced by preparing different pulp and sand with refractory materials, and stacking one layer of pulp over one layer of sand on the surface of the wax mold. Then, the ceramic shell made is dried, dewaxed, put in a sintering machine and sintered under the high temperature of 900~1400°C. Since sintering is an essential part to make the shell mold, the sintering quality has a direct influence on the quality of shell mold as well as that of final castings.

[0004] In the prior art, platform-type sintering furnace or tunnel-type sintering furnace is always applied for sintering shell mold. During the sintering, the temperature is heated to shell mold sintering temperature for sintering. The difference between two is: According as whether or not ventilation chimney is provided, the platform-type sintering furnace is divided into an enclosed platform-type sintering furnace, as shown in Fig. 1-1 and a convective platform-type sintering furnace as shown in Fig. 1-2. For the former, its sintering process is: First, the shell mold is dewaxed, its sprue cup is downturned on the platform of sintering furnace chamber 1, then closure door 3 is closed, at the same time, control system 4 controls heating apparatus 2 to heat sintering furnace chamber 1 until the temperature in sintering furnace chamber 1 reaches the shell mold sintering temperature, and control system 4 controls the heating apparatus to maintain the temperature in the sintering furnace chamber 1 so as to sinter the shell mold, and the sintering furnace chamber 1 is approximately closed during the whole process. For the latter, its sintering process is: First, the shell mold is dewaxed, its sprue cup is downturned on the platform of sintering furnace chamber 1, then closure door 4 is closed, at the same time, control system 5 controls heating apparatus 2 to heat sintering furnace chamber 1 until the temperature in sintering furnace chamber 1 reaches the shell mold sintering temperature, and control system 5 controls the heating apparatus to maintain the temperature in the sintering furnace chamber 1 so as to sinter the shell mold. Since the sintering furnace chamber 1 is connect with open convection pass 3, the whole sintering process is at thermal convection.

[0005] Current tunnel-type sintering furnace is shown as Fig. 2. Its sintering process is: After the shell mold is dewaxed, its sprue cup is downturned on a slab trolley 3, which is pushed into the sintering furnace chamber 1, then closure door 4 is closed, at the same time, control system 5 starts heating apparatus 2 to heat sintering furnace chamber 1 until the temperature in sintering furnace chamber 1 reaches the shell mold sintering temperature, and control system 5 controls the heating apparatus to maintain the temperature in the sintering furnace chamber 1 so as to sinter the shell mold. Since guide rails are laid under the sintering furnace chamber 1, it can't be fully closed, and the whole sintering process is at thermal convection.

[0006] When current sintering furnace sinters the shell mold, the sprue cup is dpwnturned for the purpose of preventing the grog generated during the process of shell mold sintering falling into the shell mold, which has an influence on final quality of castings made by casting.

[0007] There are following problems using current sintering method and apparatus;

1. Castings, made through casting the molten steel in the shell mold sintered with the platform-type sintering furnace, are usually featured with sand holes.
2. For the shell mold made by the enclosed platform-type sintering furnace, the molten steel casting tends to spatter outwards; in addition, castings made tend to be scrapped due to the existence of penetrating pores.
3. Decarbonization tends to appear when castings demould and there would be corrosion on the surface of castings when using the convective platform-type sintering furnace and tunnel-type sintering furnace.
4. In case of using platform-type sintering furnace for continuous production, on castings made through pouring molten steel in the second-furnace or subsequent sintered shell mold, there is always the gray trim

- burr or convex watermark, or shallow-concave round-bottom watermark shaped like a chicken claw - concave watermark.

[0008] The problems above would give rise to unstable castings in quality, resulting in high defective rate and rejection rate of castings. Current solution is usually to further process the defective products intensively so as to meet the required precision of castings and recycle the waste. Although current solution solves the quality problem of castings to some extent, yet it greatly reduces the production efficiency, improves the production cost and it is hard to produce castings with high-precision.

Summary

[0009] To solve problems above, one of purposes of the present invention is to provide a shell mold sintering method, which includes following steps:

S1.producing a shell mold, wherein carbon powder needs to be added during a shell mold production process;

S2.dewaxing the produced shell mold, and then placing the mold into a sintering apparatus while ensuring there is adequate oxygen content in a sintering furnace, increasing the temperature to a combustion temperature of shell mold wax, and keeping the temperature in the sintering furnace until residual wax in the shell mold is completely burned off;

S3.reducing oxygen content in the sintering furnace, and increasing the temperature to the sintering temperature of the shell mold;

S4.keeping the temperature within the sintering furnace at the sintering temperature of the shell mold in a low-oxygen or oxygen-free environment, until sintering of the shell mold is completed.

[0010] Further, the step S1 of adding carbon powder during the shell mold production process specifically is:

A. adding carbon powder to the third layer of the shell mold from inside to outside if the shell mold is of four-layer or five-layer shell mold structure;

B. adding carbon powder to the third and the fourth layers of the shell mold from inside to outside if the shell mold is of six-layer or seven-layer shell mold structure;

C. adding carbon powder to the third, the fourth and the fifth layers of the shell mold from inside to outside if the shell mold is of over seven-layer shell mold structure.

[0011] Further, the total addition of carbon powder is above 15% of shell mold mass.

[0012] Preferably, addition of carbon powder at each layer increases layer-by-layer from the internal additive layer.

[0013] Preferably, the total addition of carbon powder is 15%~20% of shell mold mass.

[0014] Preferably, the carbon powder is graphite.

[0015] Further, in step S2, sufficient oxygen content can be ensured under the sintering environment through making turbulent airflow in the sintering environment.

[0016] Further, the combustion temperature of the shell mold wax in step S2 can be set as 600°C~800°C.

[0017] Further, the holding time to maintain the temperature in the sintering furnace in step S2 is preset according to the shape and complexity of shell mold.

[0018] Preferably, the holding time can be set as 5~20min.

[0019] Further, the holding time to maintain the temperature in the sintering furnace to be the sintering temperature of shell mold in step S4 is preset according to the shape and complexity of shell mold.

[0020] Preferably, the holding time can be set as 30~180min.

[0021] Further, the sintering temperature of the shell mold in the step S4 is preset according to the shape and complexity of shell mold.

[0022] Preferably, the sintering temperature of the shell mold can be set as 1200~1400°C.

[0023] The other purpose of the present invention is to provide a sintering device based on the shell mold sintering method above. The device is comprised of a shell mold placement platform, a heating apparatus, an air-blowing apparatus, an exhaust flue, a control system, a sintering chamber and a closure door; a shell mold sprue cup to be sintered is downturned on the shell mold placement platform; the shell mold placement platform is installed in the sintering chamber; the closure door can open or close the sintering chamber; the heating apparatus can heat the sintering chamber; one end of the air inlet of the air-blowing apparatus is located out of the sintering apparatus, and one end of the air outlet is located in the sintering chamber; a switching device is installed in the exhaust flue; one end of its air inlet is located in the sintering chamber, and one end of its air outlet is located out of the sintering apparatus; the control system comprises a temperature sensing module and a control module, wherein the temperature sensing module is installed in the sintering chamber, capable of sensing an ambient temperature in the sintering chamber and feeding back temperature data to the control module; the control module is connected with the heating apparatus, air-blowing apparatus and the switching device in the exhaust flue, capable of controlling on or off of the heating apparatus, air-blowing apparatus and exhaust flue according to a preset program.

[0024] The working process of the sintering apparatus is:

a. putting the shell mold to be sintered on the shell mold placement platform, starting the device, the control device controlling the heating apparatus, air-blowing apparatus and the exhaust flue to be on;

b. controlling on or off of the heating apparatus to maintain the temperature of the sintering chamber within the set temperature range of the first stage when the temperature of the sintering chamber reaches the set temperature of the first stage, the holding time being preset according to the shape and the complexity of the shell mold;

c. shutting down the air-blowing apparatus and the exhaust flue, while opening the heating apparatus, continuing to heat to the set temperature of the second stage;

d. controlling on or off of the heating apparatus to maintain the temperature of the sintering chamber within the set temperature range of the second stage, the holding time being preset according to the shape and the complexity of the shell mold.

[0025] Preferably, the set temperature of the first stage may be 600°C~800°C.

[0026] The set temperature range set of the first stage is from the wax combustion temperature to the carbon powder combustion temperature.

[0027] Preferably, the set temperature range of the first stage may be 600°C~800°C.

[0028] Preferably, the set temperature of the second stage may be 1200°C~1400°C.

[0029] The set temperature of the second stage is the shell mold sintering temperature and the set temperature range of the second stage can be shell mold sintering temperature ±100°C.

[0030] Preferably, the set temperature range of the second stage may be 1200°C~1400°C.

[0031] Further, the shell mold placement platform can be fixedly installed in the sintering chamber or movably linked with the sintering chamber.

[0032] Further, the air-blowing apparatus and exhaust flue can form turbulent airflow in sintering chamber and the wind of the turbulent airflow is not strong enough to blow the grog into the shell mold.

[0033] Further, a switching device B is provided within the air-blowing passage of air-blowing apparatus to open or close the air-blowing passage.

[0034] Preferably, the switching device B in the air-blowing apparatus is installed outside the air outlet of sintering chamber wall where the air-blowing apparatus is located.

[0035] Preferably, the switching device in exhaust flue is installed outside the air inlet of sintering chamber wall where the exhaust flue is located.

[0036] Further, the control system also includes an oxygen concentration monitoring module, of which one end is connected into the sintering chamber to monitor oxygen concentration in the sintering chamber in real time, while the other end is connected with a control module to feed back the real-time oxygen concentration in the sintering chamber to the control module; the control module can control the output power of air-blowing apparatus according to acquired oxygen concentration.

[0037] Further, one end face of the shell mold placement platform for placing shell mold is provided with a groove, and the width of the groove enables the grog generated through shell mold sintering to fall into the groove without causing that the shell mold itself slides into the groove to give rise to shell mold tilting.

[0038] Further, the turbulent airflow, formed in the sintering chamber through the air-blowing apparatus and exhaust flue, can get into the shell mold along the groove from sprue cup of the shell mold.

[0039] Preferably, in case of only one sprue cup for the shell mold, the turbulent airflow can form convection inside the shell mold; in case of multiple sprue cups for the shell mold, the turbulent airflow can form circulation in the shell mold.

[0040] Preferably, a detachable or replaceable slab is placed or installed on the shell mold placement platform with the shell mold placed on one end face of the slab, the end face of the slab for placing the shell mold is provided with a groove whose width enables the grog generated through shell mold sintering to fall into the groove without causing the shell mold itself to slide into the groove, which would give rise to shell mold tilting.

[0041] Preferably, the slab is a composite slab is a combined slab, formed by a plurality of sub-structural slabs on the whole.

[0042] Further, the groove is obtained through a wavy end face. At this point, the shell mold sprue cup wall to be sintered is downturned on the crest of wavy end face.

[0043] Preferably, the crest for wave structure of the wavy end face is 3~10cm.

[0044] Further, the exhaust flue is installed with a vibration device and a soot door, and the vibration device can shake off the smoke dust attached on the inner wall of exhaust flue to the soot door of flue.

[0045] Preferably, the vibration device includes: a vibrating motor, a drive device and a control device. The vibrating motor is movably installed on the outside wall of upstake flue; the control device is connected with the vibrating motor and can control the on or off of the vibrating motor, at the same time, it can control the movement of vibrating motor along the outside wall of upstake flue through the drive device.

[0046] Preferably, the drive device includes a drive motor and a motional orbit. The control device is connected with the drive motor and can control the movement of vibrating motor along the motional orbit outside wall of upstake flue through the drive motor according to preset program.

[0047] The shell mold sintering method and apparatus in the present invention are featured with following advantages:

1. When using the shell mold made by the shell mold sintering method and apparatus in the present invention for molten steel casting, there is almost neither outward spattering of molten steel nor penetrating pore for castings made.

2. When using the shell mold made by the shell mold sintering method and apparatus in the present invention for molten steel casting, there is almost no mold wall reaction and the precision of castings is enhanced.

3. The shell mold sintering method and apparatus in

the present invention can be used for continuous production of shell mold, and there is almost no convex or concave watermark on castings during the continuous production.

4. There is almost no sand hole for castings made with shell mold casting by means of the shell mold sintering method and apparatus in the present invention.

5. Castings poured with shell mold through the shell mold sintering method and apparatus in the present invention are stable in quality, with low defective rate and substandard rate, and the production efficiency is far above that of current sintering method and apparatus.

6. Proper addition of carbon powder can not only ensure sufficient carbon powder for oxygen penetration protection during casting the molten steel, but also guarantee the intensity of shell mold that would not be weakened due to the massive combustion of carbon powder; proper addition of carbon powder ensures both fluffy processing of shell mold at the needed shell and sufficient intensity of shell mold.

Brief Description of the Drawings

[0048]

Fig. 1-1 represents the existing enclosed platform-type sintering furnace;

Fig. 1-2 represents the existing convective platform-type sintering furnace;

Fig. 2 represents the existing tunnel-type sintering furnace;

Fig. 3 represents the structure of sintering apparatus in the present invention;

Fig. 4 represents the structure of sintering chamber of the sintering apparatus in the present invention;

Fig. 5 represents the structure of composite wavy sintering slab in the present invention.

Detailed Description

[0049] In order to make the purpose, technical scheme and advantages of the present invention more clear, the figures shall be referred to further describe the present invention. It should be understood that the embodiments depicted herein are only used for explaining the present invention, without any limit to the present invention.

[0050] After the study on the prior art by the inventor, the reasons why the current sintering method and sintering apparatus would give rise to problems above are respectively:

1. When using the shell mold sintered by the current enclosed platform-type sintering furnace for casting molten steel, it results in molten steel spattering outwards and penetrating pores on castings, the reason is: the current sintering method is to heat the sintering furnace to the sintering temperature of shell mold and maintain for some time until the completion of shell mold sintering, with the sintering temperature of shell mold at 1200~1400°C usually; then the shell mold is often unable to completely remove the wax that is used for making shell mold before putting into the sintering furnace (heating the shell mold and pour out the wax after it melts), especially in the case of large shell mold or complex structure, at this point, the wax that is not completely removed would be carbonized directly under the environment of high temperature and low oxygen, and attached inside the shell mold in the form of residual carbon. When pouring molten steel into the shell mold, the residual carbon in the shell mold forms CO high-pressure gas because of the high temperature of molten steel and rapid reaction of air combustion in the mold. There is no reaction between CO and molten steel. On account of the compact and high-strength internal layer on which the shell mold contacts the molten steel, CO high-pressure gas only can be discharged reversely, resulting in the molten steel splashing outwards and the formation of a penetrating pore on the casting by residual CO gas.

2. When using the shell mold sintered by convective platform-type sintering furnace and tunnel-type sintering furnace, the decarbonization phenomena may appear at the time of casting demoulding and surface corrosion phenomenon may appear on casting, the reasons of appearing these phenomena are as follows: in order to prevent mold wall reaction and enhance the air permeability of shell mold in the manufacturing operation of shell mold, the carbon powder is usually added; however, because of the sintering environment of convective platform-type sintering furnace and tunnel-type sintering furnace is semi-enclosed with high oxygen content, the added carbon powder will be exhausted quickly by oxidizing reaction, so that the made shell mold cannot play its protective role. When pouring molten steel, a large number of oxygen from external environment penetrates into the internal layer of the shell mold; when the oxygen penetrates into the internal layer surface on which molten steel contacts shell mold and under the high temperature effect of molten steel, metal oxide in molten steel and monox in the internal layer of shell mold react to form low-melting silicate, namely mold wall reaction. Consequently, the decarbonization phenomenon appears at the time of casting demoulding and surface corrosion phenomenon appears on the casting. Taking advantage of silica sol with high concentration to make shell mold will further sharpen the mold wall reaction.

3. When using the existing sintering furnace for continuous production, the reason why burr/ convex watermark or concave watermark appears on the casting that is made by the second furnace or subsequently sintered shell mold with pouring molten steel

is as follows: when continuously sintering the second furnace and subsequent shell mold, because of the extremely high temperature in furnace and relatively poor thermal conductance of shell mold, the internal and external temperature difference of the shell mold is large, and then the external shell mold expands larger than internal shell mold. Consequently, fine crack appears on the internal shell mold. If the generated fine crack is not wide enough for the molten steel to pass, then the accumulated gas in fine crack will produce instant high pressure by expansion under the high temperature, thereby the concave watermark appear on the surface of casting. If the generated fine crack is wide enough for molten steel to pass, then the molten steel passes through the crack, thereby appearing projected burr or convex watermark on the casting.

4. When using the shell mold sintered by the platform-type sintering furnace, the casting made after pouring molten steel generally has sand hole, for which the reason is as follows: during the sintering process of shell mold, the grog will be produced at the same time- namely the ceramic body on the external layer of shell mold cannot maintain its properly structural strength and drops out. The dropped grog accumulates on the platform, by this time, the grog is prevented from dropping out in the sintering process due to the sprue cup downturn, but the residual grog attached to the sprue cup will slip into the internal part of shell mold when pouring molten steel. The slipped grog forms a heat-resistant structure under the high temperature effect of molten steel, thereby, the sand-shape pit appears on the surface of the casting which is called sand hole. Now there has technology to place sand hole, namely adopt the method of timely cleaning the residual grog, however, the existing technology has following issues: (1) in order to clean up the grog, the production must be stopped and the temperature in the sintering furnace must be lowered; (2) the condensation usually happens when lowering the temperature of grog, which is difficult to remove; forced removal even will damage the sintering platform of the sintering machine. Existing cleaning technology extremely reduces productivity and increases production costs.

[0051] On the basis of the above research findings, the inventor provides a new shell mold sintering method, which includes the following steps:
S1. Producing a shell mold, wherein graphite needs to be added during the shell mold production process.

[0052] The additive amount of graphite shall be 20% of the shell mold mass; the details of additive positions of graphite are as follows:

A. adding carbon powder to the third layer of the shell mold from inside to outside if the shell mold is of four-layer or five-layer shell mold structure;

B. adding carbon powder to the third and the fourth layers of the shell mold from inside to outside if the shell mold is of six-layer or seven-layer shell mold structure;

C. adding carbon powder to the third, the fourth and the fifth layers of the shell mold from inside to outside if the shell mold is of over seven-layer shell mold structure.

[0053] Additive amount of carbon powder at each layer increases layer-by-layer from the internal additive layer.

[0054] According to one embodiment of the present invention, the additive amount of graphite shall be 15% of the shell mold mass.

[0055] S2. Dewaxing the produced shell mold, and then placing the mold into a sintering apparatus while ensuring there is adequate oxygen content in a sintering furnace, and keeping the temperature in the sintering furnace at 600°C ~800°C until residual wax in the shell mold is completely burned off.

[0056] According to one embodiment of the present invention, the holding time of Step S2 is preset to be 5~20min according to the shape and complexity of shell mold.

[0057] S3. Reducing oxygen content in the sintering furnace, and increasing the temperature to the sintering temperature of the shell mold.

[0058] S4. Keeping the temperature within the sintering furnace at the sintering temperature of the shell mold in a low-oxygen or oxygen-free environment, until sintering of the shell mold is completed.

[0059] According to one embodiment of the present invention, the time to maintain the temperature in sintering furnace as the sintering temperature of shell mold in step S4 is preset to be 30~180min according to the shape and complexity of shell mold.

[0060] According to one embodiment of the present invention, the sintering temperature of the shell mold in step S4 is preset to be 1200°C~1400°C according to the shape and complexity of shell mold.

[0061] Based on the above sintering method, the present invention also provides a shell mold sintering apparatus. As shown in Fig. 3, the apparatus comprises shell mold placement platform 1, heating apparatus 2, air-blowing apparatus 3, exhaust flue 4, control system 5, sintering chamber 6 and closure door 7.

[0062] The shell mold placement platform 1 is installed in the sintering chamber 6, the shell mold sprue cup to be sintered is downturned on the shell mold placement platform 1, and the surface the shell mold placement platform 1 contacting with the shell mold sprue cup is of wavy structure with a crest height of 10cm, at this moment, the sprue cup is downturned and placed on crest by hanging in the air.

[0063] According to one embodiment of the present invention, the crest height of the shell mold placement platform 1 can be 3cm.

[0064] According to one embodiment of the present invention, the crest height of the shell mold placement platform 1 can be 5cm.

[0065] According to one embodiment of the present invention, the shell mold placement platform 1 can be installed in the sintering chamber 6 with a detachable movable connection structure.

[0066] According to one embodiment of the present invention, the wavy structure on the shell mold placement platform 1 can be replaced by other structures with groove.

[0067] According to one embodiment of the present invention, as shown in Fig. 5, the shell mold placement platform 1 is a slab platform, on which a sintered plate 11 combined by multiple sub-slabs 12 is placed. The shell mold is downturned on the sintered plate 11. The surface the sintered plate 11 contacting with the shell mold is of wavy structure with a crest height of 10cm, at this moment, the sprue cup of shell mold is downturned and placed on the crest of the sintered plate 11 by hanging in the air.

[0068] According to one embodiment of the present invention, the crest height of the sintered plate can be 3cm.

[0069] According to one embodiment of the present invention, the crest height of the sintered plate can be 5cm.

[0070] According to one embodiment of the present invention, the wavy structure on the sintered plate can be replaced by other structures with groove.

[0071] The closure door 7 can open or close the sintering chamber 6. The heating apparatus 2 can heat the sintering chamber 6.

[0072] The air inlet of the air-blowing apparatus 3 is provided outside the sintering apparatus, while the air outlet is provided in the sintering chamber 6. The switching device 31 is installed in the air-blowing passage, which can open or close the air-blowing passage. The switching device 31 in the air-blowing apparatus is installed outside the air outlet of air-blowing apparatus on the wall of sintering chamber 6.

[0073] The switching device 41 is installed in the exhaust flue 4, with the air inlet provided in the sintering chamber and the air outlet provided outside the sintering apparatus. The switching device in the exhaust flue is installed outside the air inlet of exhaust flue on the wall of sintering chamber 6. The exhaust flue is installed with a vibration device 42 and a soot door 43, and the vibration device can shake off the smoke dust attached on the inner wall of exhaust flue to the soot door of flue. The vibration device 42 includes a vibrating motor, a drive device and a control device. The vibrating motor is movably installed on the outside wall of upstake flue; the drive device includes drive motor and motional orbit; the control device is connected with the vibrating motor and drive motor, can control the on or off of the vibrating motor through the preset program, and can control the movement of the vibrating motor along the motional orbit on the outside wall of upstake flue through the drive motor. The smoke dust shaken off can be removed out from the soot door 43.

[0074] As shown in Fig. 4, a turbulent airflow is formed in the sintering chamber 6 under the combined action of air-blowing apparatus 3 and exhaust flue 4. The turbulent airflow can flow into the shell mold from the place where the sprue cup of shell mold is placed by hanging in the air. In the case of only one sprue cup for shell mold, the turbulent airflow can form convection in the shell mold; in the case of several sprue cups for shell mold, turbulent airflow can form circulation in the shell mold. And the wind blown in by the air-blowing apparatus 3 is not strong enough to blow the grog into the shell mold.

[0075] The control system 5 comprises a temperature sensing module 51 and a control module 52. The temperature sensing module 51 is installed in the sintering chamber 6, capable of sensing the ambient temperature in the sintering chamber 6 and feeding back the temperature data to the control module 52; the control module 52 is connected with the heating apparatus 2, air-blowing apparatus 3 and exhaust flue 4 as well as the switching device 31 in the air-blowing apparatus 3 and the switching device 41 in the exhaust flue 4 respectively, capable of controlling the on or off of the heating apparatus, air-blowing apparatus, exhaust flue and switching devices 31 and 41 according to a preset program.

[0076] According to one embodiment of the present invention, the control system 5 also includes an oxygen concentration monitoring module, of which one end is connected into the sintering chamber 6 to monitor the real-time oxygen concentration in the sintering chamber 6, while the other end is connected with the control module 52 to feedback the real-time oxygen concentration in the sintering chamber 6 to the control module 52; the control module 52 controls the output power of the air-blowing apparatus 3 according to the acquired oxygen concentration.

[0077] The working process of the shell mold sintering apparatus of the present invention is as follows:

a. Placing the shell mold to be sintered on the sintered plate on the shell mold placement platform 1, start the device, and control the on of the heating apparatus 2, air-blowing apparatus 3, the switching device 31 in the air-blowing apparatus 3 and the switching device 41 in the exhaust flue 4 by the control device 5.

b. Controlling on or off of the heating apparatus to maintain the temperature of the sintering chamber within 600°C~800°C, when the temperature of the sintering chamber 6 reaches 700°C, with the holding time preset as 5~20min according to the shape and complexity of shell mold;

c. Turning off the air-blowing apparatus 3 as well as the switching device 31 in the air-blowing apparatus 3 and the switching device 41 in the exhaust flue 4, and turn on the heating apparatus 2 at the same time to keep heating the sintering chamber 6 until the temperature of the sintering chamber 6 reaches the sintering temperature of shell mold. The sintering temperature of shell mold can be selected as 1200°C~1400°C according to the shape and complexity of shell mold.

d. Controlling on or off of the heating apparatus to maintain the temperature of the sintering chamber within 1200°C~1400°C, with the holding time preset as 30~180min according to the shape and complexity of shell mold.

[0078] The advantages of the sintering method and apparatus of the present invention are:

1. A heating method of sectional type is applied, which divides the sintering process of shell mold into the waxing and sintering stages. The waxing stage ensures that full combustion reaction can be enabled with sufficient oxygen in the sintering environment and wax, so that nearly no residual carbon would be formed due to the carbonization of residual wax in the shell mold, thus preventing the molten steel splash when pouring and the existence of penetrating pores on casting. The oxygen concentration in the sintering environment is also lowered as far as possible at the sintering stage, preventing the complete burning of graphite at this stage, which would result in the severe mold wall reaction when pouring molten steel to the shell mold.
2. The surface the sintering apparatus contacting with the sprue cup of shell mold is of wavy structure. With such configuration, the contact surface between sprue cup and crest is almost the tangent surface, such that when the sprue cup is overturned for molten steel pouring, little grog at the sprue gate will be remained, then, avoiding the occurrence of sand holes.
3. A turbulent airflow can be formed in the sintering chamber under the combined action of air-blowing apparatus and exhaust flue. The turbulent airflow can flow into the shell mold from the place where the sprue cup of shell mold is placed by hanging in the air, lowering the temperature difference between the inner and outer layers of shell mold, and avoiding the cracking of the inner layer of shell mold due to the temperature difference in and out of the shell mold, which would result in the occurrence of gray trim/convex or concave watermark on casting. And the strength of the turbulent airflow is relatively weak, not enough to blow the grog into the shell mold.
4. The adoption of the combined sintered plate as the placement platform of shell mold enables the timely disassembly and replacement of sintered plate when a lot of grogs are accumulated in the groove of sintered plate, which is convenient for clearing the residual grog in the sintered plate, has slight impact on the continuous production and improves the production efficiency.
5. Proper addition of carbon powder can not only ensure sufficient carbon powder for oxygen penetration protection during casting the molten steel, but also guarantee the intensity of shell mold that would not be weakened due to the massive combustion of carbon powder; proper addition of carbon powder ensures both fluffy processing of shell mold at the needed shell and sufficient intensity of shell mold.

[0079] The adoption of the sintering method and apparatus of the present invention can not only reduce the problems of unstable casting quality in the casting process of shell mold as well as high defective and rejection rates of casting, improving the production efficiency and lowering the production cost, but also enable the production of castings with high precision.

[0080] It should be noticed and understood that various modifications and improvements can be made to the present invention described in detail above without departing from the spirit and scope of the present invention defined by the claims. Therefore, the scope of the technical scheme to be protected is not limited to any exemplary teachings given.

Claims

1. A shell mold sintering method, comprising the following steps:

S1.producing a shell mold, wherein carbon powder needs to be added during a shell mold production process;
S2.dewaxing the produced shell mold, and then placing the mold into a sintering apparatus while ensuring there is adequate oxygen content in a sintering furnace, increasing the temperature to a combustion temperature of shell mold wax, and keeping the temperature in the sintering furnace until residual wax in the shell mold is completely burned off;
S3.reducing oxygen content in the sintering furnace, and increasing the temperature to the sintering temperature of the shell mold;
S4.keeping the temperature within the sintering furnace at the sintering temperature of the shell mold in a low-oxygen or oxygen-free environment, until sintering of the shell mold is completed.

2. The shell mold sintering method according to claim 1, wherein: the step S1 of adding carbon powder during the shell mold production process specifically is:

A. adding carbon powder to the third layer of the shell mold from inside to outside if the shell mold is of four-layer or five-layer shell mold structure;

B. adding carbon powder to the third and the fourth layers of the shell mold from inside to outside if the shell mold is of six-layer or seven-layer shell mold structure;
C. adding carbon powder to the third, the fourth and the fifth layers of the shell mold from inside to outside if the shell mold is of over seven-layer shell mold structure.

3. The shell mold sintering method according to claim 2, wherein: the total addition amount of the carbon powder is over 15% of the mass of the shell mold.

4. A shell mold sintering apparatus of the shell mold sintering method according to claim 1, comprising a shell mold placement platform, a heating apparatus, an air-blowing apparatus, an exhaust flue, a control system, a sintering chamber and a closure door; a shell mold sprue cup to be sintered is downturned on the shell mold placement platform; the shell mold placement platform is installed in the sintering chamber; the closure door can open or close the sintering chamber; the heating apparatus can heat the sintering chamber; one end of the air inlet of the air-blowing apparatus is located out of the sintering apparatus, and one end of the air outlet is located in the sintering chamber; a switching device is installed in the exhaust flue; one end of its air inlet is located in the sintering chamber, and one end of its air outlet is located out of the sintering apparatus; the control system comprises a temperature sensing module and a control module, wherein the temperature sensing module is installed in the sintering chamber, capable of sensing an ambient temperature in the sintering chamber and feeding back temperature data to the control module; the control module is connected with the heating apparatus, air-blowing apparatus and the switching device in the exhaust flue, capable of controlling on or off of the heating apparatus, air-blowing apparatus and exhaust flue according to a preset program;
the shell mold placement platform can be fixedly installed in the sintering chamber or movably linked with the sintering chamber;
the air-blowing apparatus and exhaust flue can form turbulent airflow in the sintering chamber;
the working process of the sintering apparatus is:

a. putting the shell mold to be sintered on the shell mold placement platform, starting the device, the control device controlling the heating apparatus, air-blowing apparatus and the exhaust flue to be on;
b. controlling on or off of the heating apparatus to maintain the temperature of the sintering chamber within the set temperature range of the first stage when the temperature of the sintering chamber reaches the set temperature of the first stage, the holding time being preset according to the shape and the complexity of the shell mold;
c. shutting down the air-blowing apparatus and the exhaust flue, while opening the heating apparatus, continuing to heat to the set temperature of the second stage;
d. controlling on or off of the heating apparatus to maintain the temperature of the sintering chamber within the set temperature range of the second stage, the holding time being preset according to the shape and the complexity of the shell mold.

5. The shell mold sintering apparatus according to claim 4, wherein: the control system also includes an oxygen concentration monitoring module, of which one end is connected into the sintering chamber to monitor real-time oxygen concentration in the sintering chamber, while the other end is connected with the control module to feedback the real-time oxygen concentration in the sintering chamber to the control module; wherein the control module is configured to control the output power of the air-blowing apparatus according to the acquired oxygen concentration.

6. The shell mold sintering apparatus according to claim 4, wherein: one end face of the shell mold placement platform for placing the shell mold is provided with a groove, whose width can make grog generated during sintering of the shell mold fall into the groove without causing the shell mold itself to slide into the groove, which would give rise to shell mold tilting.

7. The shell mold sintering apparatus according to claim 4, wherein: a detachable or replaceable slab is placed or installed on the shell mold placement platform, with the shell mold placed on one end face of the slab, the end face of the slab for placing the shell mold is provided with a groove whose width enables the grog generated through shell mold sintering to fall into the groove without causing the shell mold itself to slide into the groove, which would give rise to shell mold tilting.

8. The shell mold sintering apparatus according to claim 7, wherein: the slab is a combined slab, formed by a plurality of sub-structural slabs on the whole.

9. The shell mold sintering apparatus according to claim 6, wherein: the groove is obtained through a wavy end face, and at this point, the sprue cup wall of the shell mold to be sintered is placed on the crest of wavy end face.

10. The shell mold sintering apparatus according to claim 7, wherein: the groove is obtained through a wavy end face, and at this point, the sprue cup wall of the shell mold to be sintered is placed on the crest of wavy end face.

11. The shell mold sintering apparatus according to claim 8, wherein: the groove is obtained through a wavy end face, and at this point, the sprue cup wall of the shell mold to be sintered is placed on the crest of wavy end face.

12. The shell mold sintering apparatus according to claim 4, wherein: the exhaust flue is further installed with a vibration device and a soot door, and the vibration device can shake off the smoke dust attached on the inner wall of exhaust flue to the soot door of the exhaust flue.

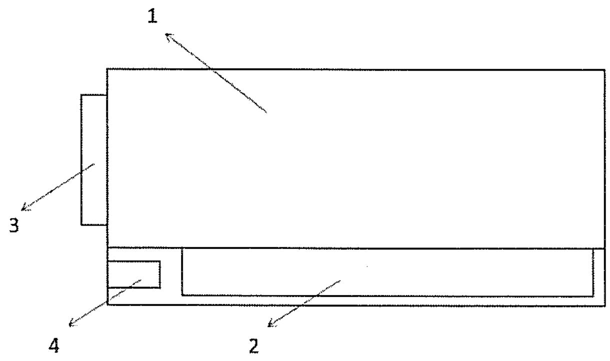

Figure 1-1

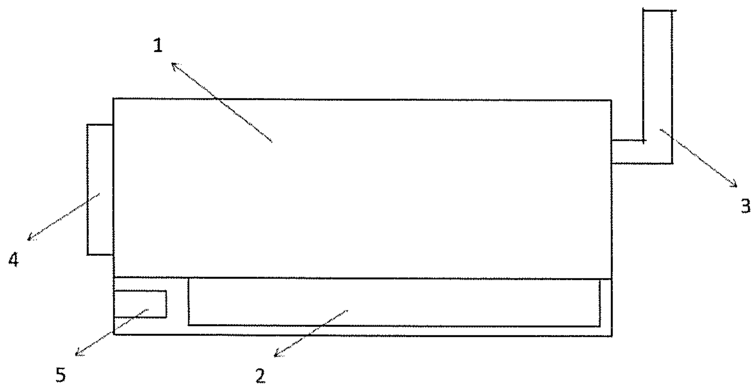

Figure 1-2

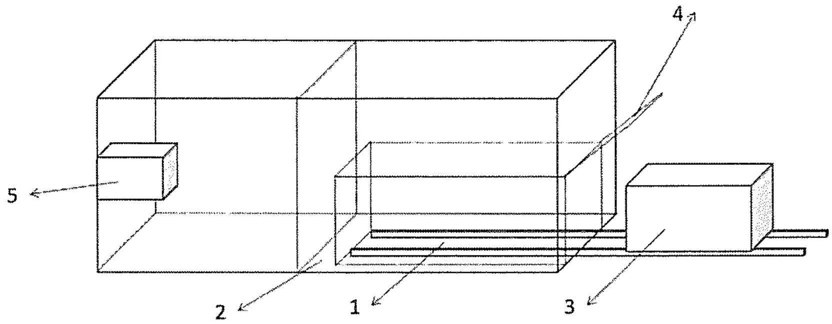

Figure 2

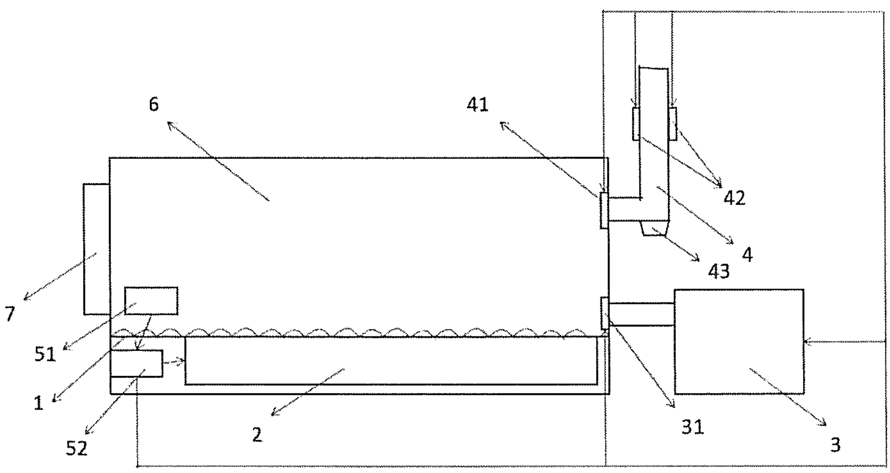

Figure 3

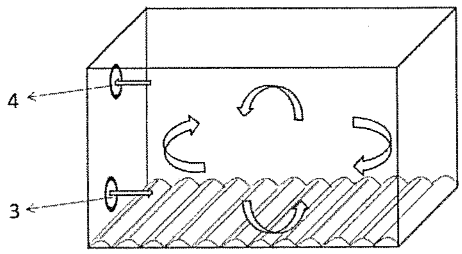

Figure 4

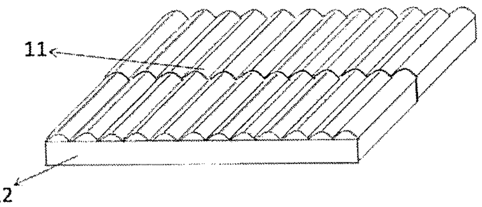

Figure 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2016/097555

A. CLASSIFICATION OF SUBJECT MATTER

B22C 9/04 (2006.01) i; B22C 7/02 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B22C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CJFD; CNABS; CNTXT; DWPI; SIPOABS: fusible pattern, shell mold, sintering furnace, flash roasting, aerobic, oxygen-free, oxygen-poor, fritting, calcining, dewaxing, baking, sintering, roasting, oxygen, investment, wax mold, furnace, molding, pattern, burning, lost wax, oxygen-enriched, anaerobic, anoxia, precision casting

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E	CN 205834112 U (CAI, Zhengda), 28 December 2016 (28.12.2016), description, paragraphs 13-46, and figures 1-5	4-12
A	CN 103611885 A (LUOYANG PENGQI INDUSTRY CO., LTD.), 05 March 2014 (05.03.2014), description, paragraphs 17-21, and figures 1-2	1-12
A	CN 2633469 Y (ZHANG, Zhonghe), 18 August 2004 (18.08.2004), the whole document	1-12
A	CN 202192223 U (NINGBO ZHICHENG NEW MATERIAL CO., LTD.), 18 April 2012 (18.04.2012), the whole document	1-12
A	CN 104325078 A (BEIJING XINGHANG MECHANICAL ELECTRICAL EQUIPMENT CO., LTD.), 04 February 2015 (04.02.2015), the whole document	1-12
A	JP 645639 A (TOYOTA MOTOR CORP.), 10 January 1989 (10.01.1989), the whole document	1-12

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

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"E" earlier application or patent but published on or after the international filing date

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 March 2017 (06.03.2017)	**20 March 2017 (20.03.2017)**

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2016/097555

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ES 2519990 A1 (UNIV LA LAGUNA et al.), 07 November 2014 (07.11.2014), the whole document	1-12
A	SU 1655653 A1 (PEREVOSHCHIKOV, E.P.), 15 June 1991 (15.06.1991), the whole document	1-12
A	KR 20140035117 A (PARK, S.G.), 21 March 2014 (21.03.2014), the whole document	1-12
A	WO 2005107976 A1 (SHONAN DESIGN CO., LTD. et al.), 17 November 2005 (17.11.2005), the whole document	1-12
A	W0 2014053189 A1 (AIR LIQUIDE et al.), 10 April 2014 (10.04.2014), the whole document	1-12

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2016/097555

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CN 2633469 Y	18 August 2004	None	
CN 202192223 U	18 April 2012	None	
CN 104325078 A	04 February 2015	None	
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KR 20140035117 A	21 March 2014	None	
WO 2005107976 A1	17 November 2005	JP 4374575 B2	02 December 2009
		JP 2005319474 A	17 November 2005
WO 2014053189 A1	10 April 2014	None	

Form PCT/ISA/210 (patent family annex) (July 2009)