提供的是一组专利申请，申请人为日立制作所，发明人包括松谷贤也、森俊太郎、大野雅夫和村尾利光。申请日为2012年10月9日，优先权日为2012年2月21日。

专利申请的背景技术包括精确铸造模具和方法的生产。该专利申请涉及一个具有内部空腔形状的模具，该模具用于生产铸件，并且包含一个涂层层和一个粘土层，粘土层粘附在覆盖层上。涂层层用于在模具表面形成一层薄膜，并由干燥的粘土层形成，该粘土层包括微米级颗粒的颗粒。

专利申请的发明内容包括一个包含多个粘土层和涂层层的多层支撑层，该支撑层在模具的外部形成一层薄膜，通过反复形成一层粘土层后干燥，然后粘土层形成一层粘土层。粘土层粘附在粘土层上。
FIG. 1

WAX PATTERN 106A

102 103 SLURRY LAYER STUCCO LAYER

(n+1)-TH LAYER) (n-TH LAYER)

104-n 102 103 n-TH BACKUP LAYER

104-1 FIRST BACKUP LAYER

101A PRIME LAYER (FIRST SLURRY LAYER)

102 SLURRY LAYER (SECOND LAYER)

103 STUCCO LAYER (FIRST LAYER)

104-1 FIRST BACKUP LAYER

105A MULTI-LAYERED BACKUP LAYER
FIG. 2

WAX PATTERN

30

106B

101a

PRIME

SLURRY LAYER

(FIRST LAYER)

101b

PRIME

SLURRY LAYER

(FIRST LAYER)

101B

PRIME LAYER

102

SLURRY LAYER

(SECOND LAYER)

103

STUCCO LAYER

(SECOND LAYER)

104-n

n-TH BACKUP LAYER

104-1

FIRST BACKUP LAYER

105B

MULTI-LAYERED BACKUP LAYER

102

SLURRY LAYER

(n-TH LAYER)

103

STUCCO LAYER

(n-TH LAYER)
FIG. 3

DES IRED STRENGTH

FIG. 4

STRENGTH

PARTICLE SIZE (μm)

PARTICLE SIZE
FIG. 5

START

PRODUCE MOLD

PRE-HEAT MOLD

POUR MOLTEN METAL

REMOVE OUTER MOLD

CORE REMOVING TREATMENT

FINISHING TREATMENT

END
FIG. 6

START

PRODUCE CORE (S12)

PRODUCE EXTERNAL METAL MOLD (S14)

PRODUCE WAX PATTERN (S16)

DIPPING (S18)

DRYING (S19)

REPEAT MORE THAN ONCE

DIPPING (S20)

STUCCOING (S21)

DRYING (S22)

IS BACKUP LAYER LAMINATED BY PREDETERMINED NUMBER OF TIMES (n)? (S23)

NO

YES

HEAT TREATMENT (S24)

END
FIG. 10

FIG. 11
PRECISION CASTING MOLD AND METHOD OF PRODUCING THE SAME

FIELD

[0001] The present invention relates to a precision casting mold and a method of producing the same.

BACKGROUND

[0002] There is a precision casting method used in the case of producing a cast product with high precision as a casting method of producing a cast product. In the precision casting method, as disclosed in Patent Literature 1, slurry is applied around a lost foam pattern (wax pattern) having the same shape as a molded component and then a first stucco (flour) layer is adhered to it and is then subjected to a drying treatment. Thereafter, three operations of the application of the slurry, the adhesion of the stucco, the drying are repeatedly performed, thereby producing a pattern for covering the outside (outer mold) of the cast product.

[0003] Here, the precision casting mold is formed in such a manner that the wax pattern is placed in slurry mainly including a silica sol, the slurry is adhered to the surface of the wax pattern, and then the slurry is dried.

[0004] Since the slurry adhered by single operation is only less and thin, the operation is repeatedly performed from several to ten times to obtain the thickness. In addition, coarse particles called a stucco material are sprinkled and adhered to the surface of the slurry to fast perform the drying, quickly ensure the thickness, or prevent dry cracks. Therefore, a dense layer and a coarse particle layer are repeated in the cross-sectional structure of the mold.

[0005] For example, the silica sol is a solution in which spherical silica particles having a particle size of about 20 nm are dispersed. When the ultrafine silica particles are adhered to the surface of relatively fine particles (from several microns to scores of microns) and coarse particles (stucco) (hundreds of microns to several millimeters) such as zircon or alumina contained in the slurry during the drying and are tightly bonded to each other by drying and heat treatment, the shape of the mold is maintained and strength is also held, so that it is possible to use as a mold.

CITATION LIST

Patent Literature


SUMMARY

Technical Problem

[0007] However, in general, it is sufficient to produce a mold using the above-described silica sol (solution in which ultrafine silica particles are dispersed), but it is necessary to hold a molten metal to control the crystal precipitation direction in, for example, a production of a unidirectional solidified blade. As a result, holding time at a high temperature (for example, about 1550°C) becomes longer. In this case, there is a problem that the silica serving as a binder is softened due to the high-temperature holding, resulting in occurring deformation of the mold.

[0008] In such a production of the unidirectional solidified blade referred herein, the blade is generally produced in such a manner that the mold is placed in a vacuum heater and is heated and held at a temperature equal to or higher than a melting point of the molten metal, and thus the molten metal is poured into the mold and the mold is taken out from the heater while being controlled for the pulling toward a lower side, so that the molten metal is cooled and solidified from the lower side.

[0009] Accordingly, for example, in the production of the unidirectional solidified blade, a mold is required which is not deformed even in the case of being held at the high temperature (for example, about 1550°C) over a long period.

[0010] The present invention has been achieved in consideration of the above problem and an object thereof is to provide a precision casting mold which is not deformed even in the case of being held at the high temperature for a long period and a method of producing the same.

Solution to Problem

[0011] According to a first aspect of the present invention in order to solve the above mentioned problems, there is provided a precision casting mold which is used to produce a cast product, including: a core having a shape corresponding to an internal hollow portion of the cast product; and an outer mold corresponding to a shape of an outer peripheral surface of the cast product, wherein the outer mold is made up of a prime layer which is formed on an inner peripheral surface and is formed from a slurry film obtained by drying slurry for the precision casting mold including mono-dispersed ultrafine alumina particles having a particle size of 1.0 μm or smaller; and a multi-layered backup layer which is formed on the outside of the prime layer by repeatedly forming a backup layer obtained by forming and drying a slurry layer formed from the slurry for the precision casting mold and a stucco layer in which a stucco material is adhered to the slurry layer.

[0012] According to a second aspect of the present invention, there is provided the precision casting mold according to the first aspect, wherein the slurry for the precision casting mold contains either of zircon powders or alumina powders having an average particle size of 50 μm or smaller, and the stucco material is either of zircon stucco particles or alumina stucco particles having an average particle size of 0.5 mm or larger.

[0013] According to a third aspect of the present invention, there is provided the precision casting mold according to the first or second aspect, wherein the prime layer has the stucco layer in which the stucco material is adhered to the slurry layer formed from the slurry for the precision casting mold.

[0014] According to a fourth aspect of the present invention, there is provided a method of producing a precision casting mold which is used to produce a cast product, the method including: a first film forming process in which a precision casting wax pattern is immersed and pulled up into/from slurry for the precision casting mold including mono-dispersed ultrafine alumina particles having a particle size of 1.0 μm or smaller and then a drying treatment is performed, thereby forming a prime layer, which is formed from a slurry film, on a surface of the wax pattern; a second film forming process in which a stucco material is sprinkled on a surface of the slurry after the wax pattern formed with the prime layer is immersed and pulled up into/from the slurry for the precision casting mold and then a drying treatment is performed, thereby forming a backup layer; a molded body forming process in which the second film forming process of forming the backup layer is repeated more than once; thereby
obtaining a molded body formed with a multi-layered backup layer; a wax removing process in which wax of the wax pattern is melted and removed from the obtained molded body; and a mold firing process in which the molded body obtained after the wax removal is subjected to a firing treatment, thereby obtaining a mold.

[0015] According to a fifth aspect of the present invention, there is provided the method of producing the precision casting mold according to the fourth aspect, wherein a stucco material is adhered to the slurry layer formed from the slurry for the precision casting mold to form a stucco layer and the stucco layer is dried during the first film forming process.

[0016] According to a sixth aspect of the present invention, there is provided the method of producing the precision casting mold according to the fourth or fifth aspect, wherein a dispersing agent of the slurry for the precision casting mold is polycarboxylic acid salts. Advantageous Effects of Invention

[0017] According to the present invention, ultrafine alumina particles having high heat resistant are used as slurry, and thus it is possible to obtain an effect that a mold is obtained which is increased in a heat resistant temperature and is not deformed in the case of being held at a high temperature (for example, 1500°C) over a long period in, for example, a production of a unidirectional solidified blade, as compared to the case of using the conventional silica sol.

BRIEF DESCRIPTION OF DRAWINGS

[0018] FIG. 1 is a configuration diagram of a dried molded body which is an outer mold.

[0019] FIG. 2 is a configuration diagram of a dried molded body which is an outer mold.

[0020] FIG. 3 is a diagram illustrating a relation between a particle size and strength.

[0021] FIG. 4 is a diagram illustrating particle size distribution of fine alumina particles.

[0022] FIG. 5 is a flowchart illustrating an example of processes in a casting method.

[0023] FIG. 6 is a flowchart illustrating an example of processes in a method of producing a mold.

[0024] FIG. 7 is an explanatory diagram schematically illustrating a process of producing a core.

[0025] FIG. 8 is a perspective view schematically illustrating a part of a metal mold.

[0026] FIG. 9 is an explanatory diagram schematically illustrating a process of producing a wax pattern.

[0027] FIG. 10 is an explanatory diagram schematically illustrating a configuration in which slurry is applied on the wax pattern.

[0028] FIG. 11 is an explanatory diagram schematically illustrating a process of producing the outer mold.

[0029] FIG. 12 is an explanatory diagram schematically illustrating some processes in the method of producing the mold.

[0030] FIG. 13 is an explanatory diagram schematically illustrating some processes in a casting method.

DESCRIPTION OF EMBODIMENTS

[0031] Hereinafter, the present invention will be described in detail with reference to the drawings. Furthermore, the present invention is not limited to the following description. Further, components in the following description include those which are easily conceived by persons skilled in the art, those which are substantially identical thereto, and those in a scope of so-called equivalents.

[0032] FIG. 1 is a configuration diagram of a dried molded body of an outer mold. FIG. 2 is a configuration diagram of another dried molded body of an outer mold.

[0033] As illustrated in FIG. 1, a precision casting mold is a precision casting mold to be used to produce a cast product and includes a core having a shape corresponding to an internal hollow portion of the cast product and an outer mold corresponding to a shape of an outer peripheral surface of the cast product, and the outer mold is made up of: a prime layer (first dried film) 101A which is formed on an inner peripheral surface and is formed from a slurry film obtained by drying slurry for the precision casting mold including mono-dispersed ultrafine alumina (Al₂O₃) particles having a particle size of 1.0 μm or smaller, and a multi-layered backup layer 105A which is formed on the outside of the prime layer (first dried film) 101A by repeatedly forming a first backup layer (second dried film) 104-1 obtained by forming and drying a slurry layer 102 formed from the slurry for the precision casting mold and a stucco layer 103 in which a stucco material is adhered to the slurry layer 102.

[0034] Here, the fine alumina particles (ultrafine alumina particles) of high purity ultrafine particles, which are subjected to mono-dispersion using, for example, a ball mill as a dispersion means, are used as a binder forming the slurry in the present invention.

[0035] The term “mono-dispersion” used herein refers to a state of being mono-dispersed into 0.5 μm even in a result of a dispersion treatment when the slurry is formed using, for example, fine alumina particles having a particle size of about 0.5 μm.

[0036] Here, the particle size of the fine alumina particles is 1.0 μm or smaller and more preferably may be in the range of 0.3 to 0.5 μm.

[0037] In the present invention, the reason why the fine alumina particles are preferably 1.0 μm or smaller in size is that results of a bending strength test are undesirable when the fine alumina particles exceed 1.0 μm in size.

[0038] FIG. 3 is a diagram illustrating a relation between a particle size and strength.

[0039] As illustrated in FIG. 3, when the particle size exceeds 1.0 μm, desired strength may not be ensured, which is undesirable.

[0040] Zircon powders (for example, having a size of 350-mesh) as flour are added to the binder of the mono-dispersed fine alumina particles, thereby obtaining the slurry for the precision casting mold.

[0041] Further, in the present invention, a case where the flour is not added may be also acceptable.

[0042] Here, polycarboxylic acid salts (for example, ammonium salts) are used to be mono-dispersed as a dispersing agent.

[0043] In addition, a ball mill using, for example, balls having a diameter of 10 to 20 mm can be exemplified as the dispersion means, but the dispersion means is not limited thereto as long as being a means that mono-disperses.

[0044] In the present invention, it is important to obtain good slurry by mono-dispersing the fine alumina particles serving as the binder.

[0045] FIG. 4 is a diagram illustrating particle size distribution of the fine alumina particles.

[0046] It is required that the mono-dispersion is performed such that the particle size distribution is narrow, and prefer-
ably, as illustrated in FIG. 4, the dispersion is performed such that the distribution is settled to the range of 0.8 d to 1.2 d from a center particle size (d).

[0047] Here, the particle size distribution was measured using the following apparatus.

[0048] A laser scattering/diffraction-type particle size distribution measuring apparatus of “CILAS 8508B-type” was used which was manufactured by Aishin Nano Technologies, Co., Ltd.

[0049] Next, a method of producing the precision casting mold will be described with reference to FIGS. 1 and 2.

[0050] (First Film Forming Process)

[0051] First, in the first film forming process, a wax pattern 30 is immersed and then pulled up into/from the slurry for the precision casting mold (hereinafter, referred to as “slurry”) including the ultrafine alumina particles, and excess slurry is dropped. Thereafter, a slurry film (first dried film) is obtained on the surface of the wax pattern 30 by a drying treatment.

[0052] In FIG. 1, the slurry film is the prime layer 101A which comes in contact with the surface of the wax pattern 30.

[0053] (Second Film Forming Process)

[0054] Next, the wax pattern 30 having the prime layer 101A is immersed and is then pulled up into/from the slurry, and the excess slurry is dropped, thereby forming the slurry layer (second layer) 102. Zircon stucco particles (having an average particle size of 0.8 mm) are sprinkled (stuccoed) on the wet slurry layer (second layer) 102 as a stucco material, thereby forming the stucco layer (first layer) 103 adhered with the stucco material. A laminated structure of the slurry layer 102 and the stucco layer (first layer) 103 is dried, so that the first backup layer (second dried film) 104-1 is formed on a prime layer (first dried film) 101.

[0055] (Molded Body Forming Process)

[0056] The similar operation as the second film forming process of forming the first backup layer 104-1 is repeated more than once (for example, 6 to 10 times), thereby obtaining a dried molded body 106A which is the outer mold having a predetermined thickness of the multi-layered backup layer 105A in which the slurry layer ((n+1)-th layer) 102 and the stucco layer (n-th layer) 103 are alternately laminated.

[0057] The dried molded body is put in, for example, an autoclave of 150°C, so that wax constituting the wax pattern 30 is melted and then is discharged.

[0058] Thereafter, the pattern is subjected to a heat treatment at 1,000°C, thereby obtaining the precision casting mold.

[0059] The obtained precision casting mold was not deformed even in a strength test at 1500°C as indicated in a test example to be described below, which had high strength. In contrast, a softening behavior was confirmed in the case of using the conventional silica sol.

[0060] In addition, as illustrated in FIG. 2, a prime stucco layer 101B adhered with the stucco material may be formed on a prime slurry layer 101A in a prime layer and may be then dried, thereby forming a prime layer 101B.

[0061] Further, as in the prime layer 101B, when the stucco material is adhered, it is possible to obtain a dried molded body 106B of an outer mold having a multi-layered backup layer 105B in which the slurry layer and the stucco layer 103 of the multi-layered backup layer 105B have the same laminated number (n layers).

[0062] In the present invention, although zircon powders were used as flour, it is possible to obtain the similar precision casting mold even when alumina powders other than the zircon powders are used as the flour and alumina stucco particles are used instead of the zircon stucco particles as a stucco material.

[0063] Further, the relation between the flour and the stucco material is not limited, but either of the zircon powders or the alumina powders may be used as the flour and either of the zircon stucco particles or the alumina stucco particles may be used as the stucco material.

[0064] Although the particle size of the flour is 350-mesh, the present invention is not limited thereto, but preferably uses particles of, for example, about 5 to 50 µm and particles having an average particle size of, for example, 50 µm or smaller.

[0065] Although the particle size of the stucco particles is 0.8 mm, the present invention is not limited thereto, but preferably uses particles of, for example, about 0.4 mm to 2 mm and particles having an average particle size of, for example, 0.5 mm or larger.

[0066] A casting method using the precision casting mold according to the present invention will be described below.

[0067] FIG. 5 is a flowchart illustrating an example of processes in the casting method. The casting method will be described below with reference to FIG. 5. Here, the processes illustrated in FIG. 5, may be fully automatically executed or may be executed in such a manner that an operator operates each of apparatuses for executing each of the processes. In the casting method of the present embodiment, a mold is produced (step S1). The mold may be previously produced or may be produced every time a casting process is executed.

[0068] The method of producing the mold of the present embodiment to be executed in step S1 will be described below with reference to FIGS. 6 to 12. FIG. 6 is a flowchart illustrating an example of processes in the method of producing the mold. Here, processes illustrated in FIG. 6, may be fully automatically executed or may be executed in such a manner that an operator operates each of apparatuses for executing each of the processes.

[0069] In the method of producing the mold, a core is produced (step S12). The core has a shape corresponding to an internal hollow of a cast product to be produced with the mold. That is, the core is disposed at a portion corresponding to the internal hollow of the cast product and prevents inflow of a metal, which is a material for the cast product, during casting. Hereinafter, a process of producing the core will be described with reference to FIG. 7. FIG. 7 is an explanatory diagram schematically illustrating the process of producing the core. In the method of producing the mold, as illustrated in FIG. 7, a metal mold 12 is prepared (step S101). The metal mold 12 has a hollow region corresponding to the core. The hollow portion of the core is a convex portion 12a. Further, in FIG. 7, the metal mold 12 is illustrated in cross section, but the metal mold 12 becomes basically the hollow for covering an entire periphery of the region corresponding to the core, except for an opening through which a material is poured into a space and a hole through which air is discharged. In the method of casting the mold, as indicated by an arrow 14, ceramic slurry 16 is poured into the inside of the metal mold 12 from the opening through the material is poured into the space of the metal mold 12. Specifically, a core 18 is produced by so-called injection molding which sprays the ceramic slurry 16 into the inside of the metal mold 12. In the method of producing the mold, after the core 18 is produced inside the metal mold 12, the core 18 is detached from the metal mold 12 and the detached core 18 is placed in a firing furnace 20,
thereby being fired. Thus, the core 18 formed of a ceramic is fired and hardened (step S102). In the method of casting the mold, the core 18 is produced in the manner described above. Further, the core 18 is formed of a material capable of being removed with a core removing treatment such as a chemical treatment after the cast product is hardened.

[0070] In the method of producing the mold, after the core 18 is produced, an external metal mold is produced (step S114). The external metal mold has a shape in which an inner peripheral surface thereof corresponds to the outer peripheral surface of the cast product. The metal mold may be formed of a metal or may be formed of a ceramic. FIG. 8 is a perspective view schematically illustrating a part of the metal mold. A metal mold 22a illustrated in FIG. 8 is configured such that a concave portion formed on the inner peripheral surface corresponds to the outer peripheral surface of the cast product. Further, in FIG. 8, only the metal mold 22a is illustrated, but corresponding to the metal mold 22a, a metal mold corresponding to the metal mold 22a is also produced in a direction to close the concave portion formed on the inner peripheral surface. The method of producing the mold is a type in which the inner peripheral surface corresponds to the outer peripheral surface of the cast product when two metal molds are fitted to each other.

[0071] In the method of producing the mold, after the external metal mold is produced, a wax pattern is produced (step S116). The description will be made below with reference to FIG. 9. FIG. 9 is an explanatory diagram schematically illustrating a process of producing the wax pattern. In the method of producing the mold, the core 18 is installed at a predetermined position of the metal mold 22a (step S110). Thereafter, a metal mold 22b corresponding to the metal mold 22a covers a surface on which the concave portion of the metal mold 22a is formed, so that the metal molds 22a and 22b surround the periphery of the core 18 and a space 24 is formed between the core 18 and the metal molds 22a and 22b. In the method of producing the mold, as indicated by an arrow 26, a pouring of a WAX 28 starts to be poured from a pipe connected to the space 24 into the inside of the space 24 (step S112). The WAX 28 is, for example, wax of a relatively low-melting point material which is melted when being heated to a predetermined temperature or higher. In the method of producing the mold, the entire region of the space 24 is filled with the WAX 28 (step S113). Thereafter, the WAX 28 encloses around the core 18 by solidifying the WAX 28, thereby forming the wax pattern 30. The wax pattern 30 is a wax pattern in which a portion formed of the WAX 28 has basically the same shape as the cast product of the production object. Thereafter, in the method of producing the cast product, the wax pattern 30 is separated from the metal molds 22a and 22b and then a sprue 32 is attached to the wax pattern (step S114). The sprue 32 is a mouth into which a molten metal, which is a metal melted during casting, is introduced. In the method of producing the mold, the wax pattern 30 formed of the WAX 28 is produced in the manner described above so as to have the same shape as the cast product and include the core 18 therein.

[0072] In the method of producing the mold, after the wax pattern 30 is produced, slurry is applied (dipped) (step S18). FIG. 10 is an explanatory diagram schematically illustrating a configuration in which the slurry is applied on the wax pattern. In the method of producing the mold, as illustrated in FIG. 10, the wax pattern 30 is immersed into a storage portion 41, in which slurry 40 is stored, and then is dried after being taken out therefrom (step S19). Thus, the prime layer 101A can be formed on the surface of the wax pattern 30.

[0073] Here, the applied slurry in step S18 is slurry which is directly applied on the wax pattern 30. Slurry in which the ultrafine alumina particles are mono-dispersed is used for the slurry 40. In the slurry 40, for example, zirconia having refractory fine particles of about 350-mesh is preferably used as flour. In addition, polyacrylic acid salts are preferably used as a dispersing agent. In addition, a trace of an antifoaming agent (silicon-based substance) or a wettability improving agent of, for example, 0.01% is preferably added to the slurry 40. By the addition of the wettability improving agent, adhesive property of the slurry 40 can be improved with respect to the wax pattern 30.

[0074] In the method of producing the mold, as illustrated in FIG. 10, a slurry application is performed with the slurry 40, and the applied slurry is dried, so that the wax pattern having the prime layer (first dried film) 101A is further applied (dipped) with the slurry (step S20). As illustrated in FIG. 11, stuccoing process of sprinkling the zircon stucco particles (having an average particle size of 0.8 mm) as a stucco material 54 is performed on the surface of the wet slurry (step S21). Thereafter, the stucco material adhered to the surface of the slurry layer is dried, thereby forming the first backup layer (second dried film) 104-1 on the prime layer (first dried film) 101A (step S22).

[0075] A process of determining whether the similar operation as the forming process of the first backup layer (second dried film) 104-1 is repeated more than once (for example, two to six times) is performed (step S23). An n-th backup layer 104-n is laminated by a predetermined number of times (n) (step S23: Yes), thereby obtaining the dried molded body 106A which is the outer mold formed with the multi-layered backup layer 105A having the thickness of, for example, 10 mm.

[0076] In the method of producing the mold, after the dried molded body 106A having the multilayer structure is obtained which is formed with the prime layer 101A and the multi-layered backup layer 105A, the dried molded body 106A is subjected to a heat treatment (step S24). Specifically, the WAX between the outer mold and the core is removed, and the outer mold and the core are further fired. The description will be made below with reference to FIG. 12. FIG. 12 is an explanatory diagram schematically illustrating some processes of the method of producing the mold. In the method of producing the mold, as illustrated in step S130, the dried molded body 106A which is the outer mold having the multilayer structure formed with the prime layer 101A and the multi-layered backup layer 105A is put in an autoclave 60 and then is heated. The inside of the autoclave 60 is filled with pressurized steam, and thus the wax pattern 30 inside the dried molded body 106A is heated by the pressurized steam. Thus, the WAX constituting the wax pattern 30 is melted and a melted WAX 62 is discharged from a space 64 surrounded by the dried molded body 106A.

[0077] In the method of producing the mold, when the melted WAX 62 is discharged from the space 64, as illustrated in step S131, a mold 72 is produced in which the space 64 is formed in a region filled with the WAX between the dried molded body 106A which is the outer mold and the core 18. Thereafter, in the method of producing the mold, as illustrated in step S132, the mold 72 having the space 64 formed between the dried molded body 106A which is the outer mold and the core 18 is heated by a firing furnace 70. Thus, in the mold 72,
a water component or an unnecessary component contained in the dried molded body 106A which is the outer mold is removed and an outer mold 61 is formed by being further fired and cured. In the method of producing the cast product, the mold 72 is produced in the manner described above.

[0078] The casting method will be continuously described with reference to FIGS. 5 and 13. FIG. 13 is an explanatory diagram schematically illustrating some processes of the casting method. In the casting method, after the mold is produced in step S1, the mold is pre-heated (step S2). For example, the mold 72 is disposed in a furnace (vacuum furnace, firing furnace) and is heated at 800°C or higher and 900°C or lower. By the pre-heating, it is possible to suppress the damage of the mold when the molten metal (melted metal) is poured into the mold at the time of producing the cast product.

[0079] In the casting method, after the mold is pre-heated, the molten metal is poured (step S3). That is, as illustrated in step S140 of FIG. 13, a molten metal 80, that is, a dissolved raw material (for example, steel) of the cast product is poured between the outer mold 61 and the core 18 from the opening of mold 72.

[0080] In the casting method, after the molten metal 80 poured into the mold 72 is solidified, the outer mold 61 is removed (step S4). That is, as illustrated in step S141 of FIG. 13, after the molten metal 80 is hardened inside the mold 72 and becomes a cast product 90, the outer mold 61 is crushed and is then removed from the cast product 90 as a fragment 61a.

[0081] In the casting method, after the outer mold 61 is removed from the cast product 90, a core removing treatment is performed (step S5). That is, as illustrated in step S142 of FIG. 13, the cast product 90 is put in an autoclave 92 and is subjected to the core removing treatment, so that the core 18 inside the cast product 90 is dissolved and the dissolved core 94 is discharged from the inside of the cast product 90. Specifically, the cast product 90 charged into an alkaline solution inside the autoclave 92 is repeatedly pressurized and depressurized, so that the dissolved core 94 is discharged from the cast product 90.

[0082] In the casting method, after the core removing treatment is performed, a finishing treatment is performed (step S6). That is, the finishing treatment is performed on the surface of the cast product 90. Furthermore, in the casting method, inspection of the cast product is performed along with the finishing treatment. Thus, as illustrated in step S143 of FIG. 13, a cast product 100 can be produced.

[0083] In the casting method of the present embodiment, as described above, the mold is produced by a lost-wax casting method using WAX (wax), thereby producing the cast product. Here, in the method of producing the mold, the casting method, and the mold of the present embodiment, the outer mold having the multilayer structure which is the outside of the mold is formed in such a manner that the prime layer (first dried film as a first layer) 101A serving as the inner peripheral surface is formed using the ultrafine alumina particles as the slurry and the multi-layered backup layer 105A is formed on the outside of the prime layer 101A.

[0084] In addition, as described above, the prime layer may be the prime layer 101B including the slurry layer 101A added with the stucco material and the stucco layer 101B (see FIG. 2).

EXAMPLE 1

[0085] The method of producing the mold and the casting method of the present embodiment will be described below using Examples. Further, in the following Examples, a front wax pattern formed with an outer mold was a member having a width of 30 mm, a thickness of 8 mm, and a length of 300 mm, and a prime layer (first dried film) formed from a slurry layer and a multi-layered backup layer made of slurry and a stucco material are formed in the wax pattern, thereby producing a mold.

[0086] High-purity ultrafine alumina particles (Al₂O₃, having a specific surface area of 10 m²/g and a particle size of about 0.5 µm) were kneaded with a ball mill for 24 hours using polycarboxylic acid salts as a dispersing agent and thus were formed in a slurry form, thereby obtaining alumina slurry. A solid content concentration of the obtained alumina slurry is 50 wt. %.

[0087] It was confirmed that the resulting alumina particles of a dispersion treatment was mono-dispersed into 0.5 µm in the alumina slurry.

[0088] Zircon powders of 350-mesh were added to the alumina slurry as flour, thereby forming slurry for a precision casting mold.

[0089] Further, at the same time, a silicon-based substance as an antifoaming agent of 0.01% and a wettability improving agent of 0.01% were added to make as in-use slurry.

[0090] A wax body having a width of 30 mm, a thickness of 8 mm, and a length of 300 mm was prepared, after the wax body was immersed and then pulled up into/from the obtained in-use slurry, thereby adhering the in-use slurry to the surface of the wax, excess in-use slurry was dropped and a prime layer (first dried film) of the slurry was obtained on the surface of the wax body by a drying treatment.

[0091] Next, in order to obtain a second dried film, the wax body having the prime layer was immersed and then pulled up into/from the in-use slurry and excess in-use slurry was dropped.

[0092] Zircon stucco particles having an average particle size of 0.8 mm were adhered to wet slurry and then were dried, so that a second dried film (first backup layer) was formed.

[0093] The similar operation as the second dried film (first backup layer) forming process was repeated six times, so that a molded body having a multi-layered backup layer was obtained to have a thickness of about 10 mm.

[0094] The obtained dried molded body was put in an autoclave of 150°C., so that the wax was melted and then was discharged.

[0095] Thereafter, the wax pattern was subjected to a heat treatment at 1000°C., thereby obtaining the mold of Example 1.

COMPARATIVE EXAMPLE

[0096] For comparison, a trial production of a mold of Comparative Example was simultaneously performed using slurry of the conventional silica sol (solution in which spherical silica particles having a particle size of about 20 nm were dispersed) in the similar operation as in Example.

[0097] [Test]

[0098] A test piece for strength having a size 10 mm×50 mm and a thickness of 5 mm was worked from the obtained mold of Example 1 and the mold of Comparative Example was subjected to a high-temperature strength test.
In a strength test at 1500°C, a softening behavior was confirmed in the case of using the conventional silica sol.

In addition, as a result, cutting of the test piece according to Comparative Example was not clear and was bent.

In contrast, the test piece using the alumina slurry (zircon particles as a stucco material) according to the present Example was broken at 100 MPa without being deformed.

Here, the strength test was performed based on "bending strength of ceramics (1981)" by JIS R 1601.

From this test result, when a binder was slurry of ultrafine alumina particles (melting point: 2,070°C) having high heat resistance and a stucco material was zircon particles (melting point: 2,715°C), as compared to the case using the conventional silica sol, it was possible to obtain the mold which is increased in a heat resistant temperature and is not deformed even in the case of being held at a high temperature (1,550°C) for a long period in the production of a unidirectional solidified blade.

EXAMPLE 2

Slurry obtained by adding alumina powders of 350-mesh as flour instead of the zircon powders in Example 1 was used for slurry for a precision casting mold.

In addition, a mold of Example 2 was obtained by the similar operation as in Example 1 except for using alumina stucco particles having an average particle size of 0.8 mm as a stucco material.

[Test]

A test piece for strength having a size 10 mm x 50 mm and a thickness of 5 mm was worked from the obtained mold of Example 2 and the mold of Comparative Example was subjected to the similar high-temperature strength test as in Example 1.

The test piece using the alumina slurry (alumina particles as a stucco material) according to the present Example was broken at 100 MPa without being deformed.

From this test result, when a binder was slurry of ultrafine alumina particles (melting point: 2,070°C) having high heat resistance and a stucco material was alumina particles (melting point: 2,070°C), as compared to the case using the conventional silica sol, it was possible to obtain the mold which was increased in a heat resistant temperature and was not deformed even in the case of being held at a high temperature (1,550°C) for a long period in the production of an unidirectional solidified blade.

From the above, when the binder is the slurry obtained by mono-dispersing the slurry of the ultrafine alumina particles having the high heat resistance and the stucco material is the zircon powders or the alumina powders, as compared to the case using the conventional silica sol, it was possible to obtain the mold which was increased in the heat resistant temperature of the obtained mold and was not deformed even in the case of being held at a high temperature (1,550°C) for a long period in the production of an unidirectional solidified blade.

REFERENCE SIGNS LIST

<table>
<thead>
<tr>
<th>Sign Reference</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0111</td>
<td>12, 22a, 22b METAL MOLD</td>
</tr>
<tr>
<td>0112</td>
<td>12a CONVEX PORTION</td>
</tr>
<tr>
<td>0113</td>
<td>14, 26 ARROW</td>
</tr>
<tr>
<td>0114</td>
<td>16 CERAMIC SLURRY</td>
</tr>
<tr>
<td>0115</td>
<td>18 CORE</td>
</tr>
<tr>
<td>0116</td>
<td>20, 70 FIRING FURNACE</td>
</tr>
<tr>
<td>0117</td>
<td>24, 64 SPACE</td>
</tr>
<tr>
<td>0118</td>
<td>28 WAX</td>
</tr>
<tr>
<td>0119</td>
<td>30 WAX PATTERN</td>
</tr>
<tr>
<td>0120</td>
<td>32 SPRUE</td>
</tr>
<tr>
<td>0121</td>
<td>40 SLURRY</td>
</tr>
<tr>
<td>0122</td>
<td>60, 92 AUTOCLAVE</td>
</tr>
<tr>
<td>0123</td>
<td>61 OUTER MOLD</td>
</tr>
<tr>
<td>0124</td>
<td>61a FRAGMENT</td>
</tr>
<tr>
<td>0125</td>
<td>62 DISSOLVED WAX</td>
</tr>
<tr>
<td>0126</td>
<td>72 MOLD</td>
</tr>
<tr>
<td>0127</td>
<td>80 MOLTEN METAL</td>
</tr>
<tr>
<td>0128</td>
<td>90, 100 CAST PRODUCT</td>
</tr>
<tr>
<td>0129</td>
<td>94 DISSOLVED CORE</td>
</tr>
<tr>
<td>0130</td>
<td>101A, 101B PRIME LAYER</td>
</tr>
<tr>
<td>0131</td>
<td>102 SLURRY LAYER</td>
</tr>
<tr>
<td>0132</td>
<td>103 STUCCO LAYER</td>
</tr>
<tr>
<td>0133</td>
<td>104-1 FIRST BACKUP LAYER</td>
</tr>
<tr>
<td>0134</td>
<td>104-n n-TH BACKUP LAYER</td>
</tr>
<tr>
<td>0135</td>
<td>105A, 105B MULTI-LAYERED BACKUP LAYER</td>
</tr>
</tbody>
</table>

1. A precision casting mold which is used to produce a cast product, comprising:

a core having a shape corresponding to an internal hollow portion of the cast product; and

an outer mold corresponding to a shape of an outer peripheral surface of the cast product,

wherein the outer mold is made up of: a prime layer which is formed on an inner peripheral surface and is formed from a slurry film obtained by drying slurry for the precision casting mold including mono-dispersed ultrafine alumina particles having a particle size of 0.3 μm to 0.5 μm; and a multi-layered backup layer which is formed on the outside of the prime layer by repeatedly forming a backup layer obtained by forming and drying a slurry layer formed from the slurry for the precision casting mold and a stucco layer in which the stucco material is adhered to the slurry layer.

2. The precision casting mold according to claim 1, wherein the slurry for the precision casting mold contains either of zircon powders or alumina powders having an average particle size of 50 μm or smaller, and

the stucco material is either of zircon stucco particles or alumina stucco particles having an average particle size of 0.5 mm or larger.

3. The precision casting mold according to claim 1, wherein the prime layer has the stucco layer in which the stucco material is adhered to the slurry layer formed from the slurry for the precision casting mold.

4. A method of producing a precision casting mold which is used to produce a cast product, the method comprising:

a first film forming process in which a precision casting wax pattern is immersed and pulled up into/from slurry for the precision casting mold including mono-dispersed ultrafine alumina particles having a particle size of 0.3 μm to 0.5 μm and then a drying treatment is performed, thereby forming a prime layer, which is formed from a slurry film, on a surface of the wax pattern;

a second film forming process in which a stucco material is sprinkled on a surface of the slurry after the wax pattern formed with the prime layer is immersed and pulled up
into/from the slurry for the precision casting mold and then a drying treatment is performed, thereby forming a backup layer;
a molded body forming process in which the second film forming process of forming the backup layer is repeated more than once, thereby obtaining a molded body formed with a multi-layered backup layer;
a wax removing process in which wax of the wax pattern is melted and removed from the obtained molded body;
and a mold firing process in which the molded body obtained after the wax removal is subjected to a firing treatment, thereby obtaining a mold.

5. The method of producing the precision casting mold according to claim 4, wherein a stucco material is adhered to a slurry layer formed from the slurry for the precision casting mold to form a stucco layer and the stucco layer is dried during the first film forming process.

6. The method of producing the precision casting mold according to claim 4, wherein a dispersing agent of the slurry for the precision casting mold is polycarboxylic acid salts.

7. The precision casting mold according to claim 2, wherein the prime layer has the stucco layer in which the stucco material is adhered to the slurry layer formed from the slurry for the precision casting mold.

8. The method of producing the precision casting mold according to claim 5, wherein a dispersing agent of the slurry for the precision casting mold is polycarboxylic acid salts.