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Core molding apparatus and core molding method

Abstract

A core molding apparatus and a core molding method capable of reducing the possibility of the deterioration in the calculation accuracy of the amount of supply of a raw material for a core are provided. A core molding apparatus includes: a kneading tank configured to knead a raw material for a core; a raw material supply unit configured to supply the raw material to the kneading tank; a mold configured to contain a kneaded material made of the raw material kneaded in the kneading tank and to mold the core; a piston configured to inject the kneaded material contained in the kneading tank into the mold; and a control unit configured to control an amount of supply of the raw material from the raw material supply unit to the kneading tank.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS

(1) This application is based upon and claims the benefit of priority from Japanese patent application No. 2021-165851, filed on Oct. 8, 2021, the disclosure of which is incorporated herein in its entirety by reference.

BACKGROUND

(2) The present disclosure relates to a core molding apparatus and a core molding method, and in particular to a core molding apparatus and a core molding method for molding a core for casting.

(3) A core molding apparatus disclosed in Japanese Unexamined Patent Application Publication

No. 2018-069301 includes a piston for injecting a kneaded material contained in a kneading tank into a mold. The core molding apparatus obtains a difference between a predetermined reference position of the injection piston and a position thereof after the injection. The core molding apparatus obtains an amount of supply of core sand by calculating the product of the obtained difference, the specific gravity (the density) of the sand, and the cross sectional area of the kneading tank. The reference position can be obtained, for example, by experiments.

SUMMARY

(4) The inventors of the present disclosure have found the following problem.

(5) The density of the core sand before an injection may differ from the density thereof after the injection. Further, the above-described product corresponds to the change between the volume of the kneaded material in the kneading tank before the injection and the volume thereof after the injection. In such a case, the position of the piston upon the completion of the injection may widely fluctuate (i.e., deviate) from the expected position. Therefore, there is a possibility that the accuracy of the calculation (hereinafter also referred to as the calculation accuracy) of the amount of supply of the raw material for the core deteriorates.

(6) In view of the above-described problem, an object of the present disclosure is to provide a core molding apparatus and a core molding method capable of reducing the possibility of the deterioration in the calculation accuracy of the amount of supply of a raw material for a core.

(7) A first exemplary aspect is a core molding apparatus including:

(8) a kneading tank configured to knead a raw material for a core;

(9) a raw material supply unit configured to supply the raw material to the kneading tank;

(10) a mold configured to contain a kneaded material made of the raw material kneaded in the kneading tank, and to mold the core;

(11) a piston configured to inject the kneaded material contained in the kneading tank into the mold; and

(12) a control unit configured to control an amount of supply of the raw material from the raw material supply unit to the kneading tank, wherein the control unit is further configured to:

(13) calculate an amount of a change in a total volume of the kneaded material in the core molding apparatus upon completion of a predetermined injection by subtracting a kneading tank volume for the kneaded material remaining in the kneading tank after the predetermined injection from a total reference volume of the kneaded material in the core molding apparatus after the predetermined injection; and

(14) determine an amount of supply of the raw material by multiplying the amount of the change in the total volume by a density of the molded core.

(15) According to the above-described configuration, the amount of supply of a raw material is obtained by using the density of a molded core after an injection and the change in the volume of a kneaded material in the whole core molding apparatus after the injection. Therefore, the change in the density of the core after the injection from the density thereof before the injection does not affect the calculation accuracy of the amount of supply of the material for the core. Therefore, it is possible to reduce the possibility of the deterioration in the calculation accuracy of the amount of supply of a raw material for a core.

(16) Further, the core molding apparatus may further include an injection plate disposed between the kneading tank and the mold, the injection plate including a through hole which the kneaded material can pass through;

(17) the piston may make the kneaded material contained in the kneading tank pass through the through hole of the injection plate and thereby inject the kneaded material into the mold; and

(18) the control unit may calculate a total reference volume of the kneaded material by calculating a sum of:

(19) a volume of the through hole of the injection plate in which the kneaded material is contained;

(20) a volume of the mold in which the kneaded material is contained; and

(21) a kneading tank reference inner volume for the kneaded material in the kneading tank upon the completion of the predetermined injection.
(22) According to the above-described configuration, it is possible to calculate the total reference volume of the kneaded material by using the volume of the kneaded material contained in the injection plate and that in the mold, both of which can be calculated in advance, and the kneading tank reference inner volume. Therefore, it is possible to improve the calculation accuracy of the amount of supply of the raw material for the core.
(23) Further, the core molding apparatus may further include a position sensor configured to detect a position of the piston; and
(24) the control unit may be further configured to:
(25) obtain a kneading tank inner volume change amount based on a difference between a reference position of the piston upon the completion of the injection determined based on the kneading tank reference inner volume and the detected position of the piston upon the completion of the injection, the kneading tank inner volume change amount being a difference between the kneading tank reference inner volume and the kneading tank volume; and
(26) calculate the amount of the change in the total volume based on the kneading tank inner volume change amount, the volume of the through hole of the injection plate in which the kneaded material is contained, and the volume of the mold in which the kneaded material is contained.
(27) According to the above-described configuration, it is possible to calculate the amount of the change in the total volume based on the position of the piston. Therefore, it is possible to easily calculate the amount of supply of the raw material for the core for each injection.
(28) Another exemplary aspect is a method for molding a core including:
(29) supplying a raw material for the core to a kneading tank;
(30) kneading the raw material in the kneading tank;
(31) injecting a kneaded material made of the raw material kneaded in the kneading tank into a mold by a piston, and thereby molding the core;
(32) calculating an amount of a change in a total volume of the kneaded material in a core molding apparatus upon completion of a predetermined injection by subtracting a kneading tank volume for the kneaded material remaining in the kneading tank after the predetermined injection from a total reference volume of the kneaded material in the core molding apparatus after the predetermined injection; and
(33) determining an amount of supply of the raw material by multiplying the amount of the change in the total volume by a density of the molded core.
(34) According to the above-described configuration, the amount of supply of a raw material is obtained by using the density of a molded core after an injection and the change in the volume of a kneaded material in the whole core molding apparatus after the injection. Therefore, the influence of the change in the density of the core after the injection from the density thereof before the injection on the calculation accuracy of the amount of supply of the material for the core is reduced. Therefore, it is possible to reduce the possibility of the deterioration in the calculation accuracy of the amount of supply of a raw material for a core.
(35) Further, in the molding of the core, the core may be molded by making the kneaded material made of the raw material kneaded in the kneading tank pass through a through hole of an injection plate by the piston and thereby injecting the kneaded material into the mold, and
(36) the method for molding the core may further include, before the calculating of the amount of the change in the total volume of the kneaded material in the core molding apparatus after the injection, calculating a total reference volume of the kneaded material by calculating a sum of:
(37) a volume of the through hole of the injection plate in which the kneaded material is contained;
(38) a volume of the mold in which the kneaded material is contained; and
(39) a kneading tank reference inner volume for the kneaded material in the kneading tank upon the completion of the predetermined injection.

(40) According to the above-described configuration, it is possible to calculate the total reference volume of the kneaded material by using the volume of the kneaded material contained in the injection plate and that in the mold, both of which can be obtained in advance, and the kneading tank reference inner volume. Therefore, it is possible to improve the calculation accuracy of the amount of supply of the raw material for the core.
(41) Further, the calculating of the amount of the change in the total volume of the kneaded material in the core molding apparatus after the injection may further include:
(42) obtaining a kneading tank inner volume change amount based on a difference between a reference position of the piston upon the completion of the injection determined based on the kneading tank reference inner volume and the position of the piston upon the completion of the injection, the kneading tank inner volume change amount being a difference between the kneading tank reference inner volume and the kneading tank volume; and
(43) calculating the amount of the change in the total volume based on the kneading tank inner volume change amount, the volume of the through hole of the injection plate in which the kneaded material is contained, and the volume of the mold in which the kneaded material is contained.
(44) According to the above-described configuration, it is possible to calculate the amount of the change in the total volume based on the position of the piston. Therefore, it is possible to easily calculate the amount of supply of the raw material for the core for each injection.
(45) According to the present disclosure, it is possible to provide a core molding apparatus and a core molding method capable of reducing the possibility of the deterioration in the calculation accuracy of the amount of supply of a raw material for a core.
(46) The above and other objects, features and advantages of the present disclosure will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not to be considered as limiting the present disclosure.

Description

BRIEF DESCRIPTION OF DRAWINGS
(1) FIG. **1** is a cross-sectional view of a core molding apparatus according to a first embodiment;
(2) FIG. **2** is a cross-sectional view of the core molding apparatus according to the first embodiment;
(3) FIG. **3** is a cross-sectional view of the core molding apparatus according to the first embodiment;
(4) FIG. **4** is a flowchart showing a method for molding a core according to the first embodiment; and
(5) FIG. **5** is a cross-sectional diagram of a specific example of the core molding apparatus according to the first embodiment.
DESCRIPTION OF EMBODIMENTS
(6) Specific embodiments to which the present disclosure is applied will be described hereinafter in detail with reference to the drawings. However, the present disclosure is not limited to the below-shown embodiments. Further, for clarifying the explanation, the following descriptions and drawings are simplified as appropriate.
First Embodiment
(7) A first embodiment will be described with reference to FIGS. **1** to **3**. FIGS. **1** to **3** are cross-sectional views of a core molding apparatus according to the first embodiment.
(8) Note that, needless to say, right-handed xyz-coordinate systems shown in FIG. **1** and other figures are shown only for illustrating positional relations among components. In general, a z-axis positive direction is a vertically upward direction and an xy-plane is a horizontal plane. The

direction and plane are in common throughout the drawings.
(9) As shown in FIG. **1**, a core molding apparatus **100** includes a kneading tank **20**, a raw material supply unit **30**, a control unit **40**, a piston **50**, a cylinder **60**, and a mold **70**. The core molding apparatus **100** according to this embodiment further includes an injection plate **80**.
(10) The kneading tank **20** is a cylindrical member with a bottom, in which the top is opened. The cross sectional area A.sub.T of the kneading tank, which is the cross sectional area of the internal space of the cylindrical member, is preferably constant along the axial direction. A through hole **21** is formed in the bottom of the kneading tank **20**. As shown in FIG. **1**, a kneaded material S**2** is supplied to (i.e., contained in) the kneading tank **20**. For example, the kneaded material S**2** can be obtained by kneading (e.g., mixing and kneading) sand, water, water glass, and/or a liquid additive(s) such as a surfactant. Specific examples of the sand include Espearl (manufactured by Yamakawa Sangyo Co., Ltd.), Lunamos (manufactured by Kao-Quaker Co., Ltd.), Green Beads (manufactured by Kinsei Matek Co., Ltd.), and AC Alumina Sand (manufactured by Hisagoya Co., Ltd.). Note that the water glass serves as a binder. The binder is not limited to water glass, and any other appropriate compound can be selected as desired.
(11) The raw material supply unit **30** supplies the kneaded material S**2** to the kneading tank **20**. Specifically, firstly, the raw material supply unit **30** supplies sand, water, water glass, and/or a liquid additive(s) such as a surfactant to the kneading tank **20**. More specifically, the raw material supply unit **30** supplies sand having a predetermined mass to the kneading tank **20**. Further, it is preferred that the raw material supply unit **30** can change the mass of the sand supplied to the kneading tank **20** each time a core is molded. The raw material supply unit **30** kneads (e.g., mixes and kneads) sand, water, water glass, and/or a liquid additive(s) such as a surfactant in the kneading tank **20**, and supplies the kneaded material S**2** to the kneading tank **20**.
(12) As shown in FIGS. **2** and **3**, the piston **50** can be moved vertically (in the Z-axis direction) by the cylinder **60**. Note that the forward movement of the piston **50** means that the piston **50** moves vertically downward (toward the negative side in the Z-axis direction), and the backward movement of the piston **50** means that the piston **50** moves vertically upward (toward the positive side in the Z-axis direction). As shown in FIG. **2**, as the piston **50** moves forward, the kneaded material S**2** contained in the kneading tank **20** is injected into the mold **70**.
(13) The mold **70** contains the kneaded material S**2** injected by the piston **50** and molds a core therefrom. The mold **70** includes a first mold **71** and a second mold **72**, which are opened and closed. As shown in FIG. **1**, as the first and second molds **71** and **72** are closed, an internal space **73** is formed therebetween. The internal space **73** includes a cavity, a runner, and the like. The cavity has substantially the same shape as that of the above-described molded core. A volume Vn of the mold **70** in which the kneaded material S**2** is contained is substantially equal to the volume of the internal space **73**. When the first and second molds **71** and **72** are opened, a space corresponding to the internal space **73** is exposed to the outside.
(14) The injection plate **80** according to this embodiment is disposed between the kneading tank **20** and the mold **70**. The injection plate **80** includes a through hole **81** which the kneaded material S**2** can pass through. The through hole **21** of the kneading tank **20**, the through hole **81** of the injection plate **80**, and the internal space **73** of the mold **70** are continuous from one to another. The kneaded material S**2** contained inside the kneading tank **20** passes through the through hole **21** and the through hole **81**, and reaches (i.e., enters) the internal space **73** of the mold **70**. The kneaded material S**2** is contained in the through hole **81** and in the internal space **73**. The through hole **81** can contain the kneaded material S**2** having a predetermined volume Vp.
(15) The cylinder **60** includes a cylinder body **61** and a cylinder rod **62**. The piston **50** is attached to the tip of the cylinder rod **62**.
(16) Further, a position sensor **63**, e.g., a linear encoder, is provided inside the cylinder **60**. Therefore, a position signal pst indicating the position of the piston is output from the cylinder **60** to the control unit **40**. Since the position sensor **63** is disposed inside the cylinder **60**, its durability

is better that when the position sensor is disposed outside the cylinder. However, the position sensor **63** does no need to be disposed inside the cylinder **60**.

(17) The control unit **40** includes an arithmetic unit and a memory. The memory stores a predetermined program(s). The arithmetic unit loads the program stored in the memory and executes the loaded program. The control unit **40** has a hardware configuration including, as the main component, a computer including a CPU (Central Processing Unit), a ROM, a RAM, an interface (I/F), and the like. The CPU, the ROM, the RAM, and the interface are connected to each other through a data bus and the like.

(18) The control unit **40** calculate a total volume change amount ΔV (i.e., the amount ΔV of a change in the total volume) of the kneaded material S**2** in the core molding apparatus **100** upon completion of a predetermined injection by subtracting a kneading tank volume V.sub.T for the kneaded material S**31** remaining in the kneading tank **20** after the predetermined injection from a total reference volume V.sub.Mstd of the kneaded material S**2** in the core molding apparatus **100** after the predetermined injection. Note that the kneaded material S**2** in the core molding apparatus **100** after the injection corresponds to a molded article S**30** (which will be described later). A relational expression (1) between the kneading tank volume V.sub.T and the total volume change amount ΔV is shown below.

$\Delta V = V$.sub.Mstd$-V$.sub.T (1)

(19) Further, the control unit **40** determines an amount M.sub.S1 of supply (hereinafter also referred to as a supply amount M.sub.S1) of the raw material by multiplying the total volume change amount ΔV by the density ρ.sub.n of the molded core. The density ρ.sub.n of the core can be determined by measuring it in advance by experiments or the like. A relational expression (2) among the supply amount M.sub.S1 of the raw material, the total volume change amount ΔV, and the density ρ.sub.n of the molded core is shown below.

M.sub.S1$=\Delta V \times \rho$.sub.n (2)

(20) The control unit **40** may calculate the total reference volume V.sub.Mstd of the kneaded material S**2** by obtaining the sum of a volume Vp of the through hole **81** of the injection plate **80** in which the kneaded material S**2** is contained, a volume Vn of the mold **70** in which the kneaded material S**2** is contained, and a kneading tank reference inner volume V.sub.Tstd of the kneaded material S**2** in the kneading tank **20** upon the completion of the predetermined injection. A relational expression (3) among the total reference volume V.sub.Mstd, the volume Vp in the through hole **81**, the volume Vn of the mold **70** in which the kneaded material S**2** is contained, and the kneading tank reference inner volume V.sub.Tstd is shown below.

V.sub.Mstd$=Vp+Vn+V$.sub.Tstd (3)

(21) Further, the control unit **40** may obtain a kneading tank inner volume change amount ΔV.sub.T, which is a difference between the kneading tank reference inner volume V.sub.Tstd and the kneading tank volume V.sub.T, based on a difference ΔL between a reference position Lstd of the piston **50** upon the completion of the injection determined based on the kneading tank reference inner volume V.sub.Tstd and a detected position Lpst of the piston **50** upon the completion of the injection. A relational expression (4) between the reference position Lstd, the position Lpst of the piston **50** upon the completion of the injection, the kneading tank inner volume change amount ΔV.sub.T, and the kneading tank cross sectional area A.sub.T is shown below.

ΔV.sub.T$=(Lpst-Lstd)\times A$.sub.T (4)

(22) Here, a relational expression (5) among the kneading tank inner volume change amount ΔV.sub.T, the kneading tank volume V.sub.T, and the kneading tank reference inner volume V.sub.Tstd is shown below.

ΔV.sub.T$=V$.sub.T$-V$.sub.Tstd (5)

(23) Further, the control unit **40** may calculate the total volume change amount ΔV based on the kneading tank inner volume change amount ΔV.sub.T, the volume Vp of the through hole **81** of the injection plate **80** in which the kneaded material S**2** is contained, and the volume Vn of the mold **70**

in which the kneaded material S**2** is contained. Note that the volume Vp is equal to the volume of a molded article S**32** (which will be described later). Further, the volume Vn is equal to the volume of a molded article S**33** (which will be described later).

(24) Based on the above-shown expressions (1) to (5), it is possible to derive an expression (6) by which the supply amount M.sub.S1 of the raw material can be calculated.

(25)
$$
\begin{aligned}
M_{S1} &= \Delta V \times \rho_n \\
&= (V_{\mathrm{Mstd}} - V_T) \times \rho_n \\
&= (\mathrm{Vp} + \mathrm{Vn} - (V_T - V_{\mathrm{Tstd}})) \times \rho_n \\
&= (\mathrm{Vp} + \mathrm{Vn} - \Delta V_T) \times \rho_n \\
&= [\mathrm{Vp} + \mathrm{Vn} - (\mathrm{Lpst} - \mathrm{Lstd}) \times A_T] \times \rho_n
\end{aligned}
\qquad (6)
$$

(26) The reference position Lstd of the piston **50** upon the completion of the injection is based on the kneading tank reference inner volume V.sub.Tstd of the kneaded material S**2** in the kneading tank **20** upon the completion of the predetermined injection. The kneading tank reference inner volume V.sub.Tstd is preferably constant. Specifically, it is preferred that the kneading tank reference inner volume V.sub.Tstd does not fluctuate each time the piston **50** injects the kneaded material S**2**. The kneading tank reference inner volume V.sub.Tstd can be obtained, for example, by experiments. Specifically, for example, the kneading tank reference inner volume V.sub.Tstd is set to a certain value, and when a core is actually molded, the position of the piston **50** upon the completion of the injection is measured. Then, the value of the kneading tank reference inner volume V.sub.Tstd is corrected based on the deviation (i.e., the difference) of the position of the piston **50** upon completion of a target injection (i.e., upon completion of an injection of a target amount of a kneaded material). It is possible to determine the kneading tank reference inner volume V.sub.Tstd by performing the above-described series of processes at least once. It is possible to determine the reference position Lstd of the piston **50** upon completion of an injection by determining the kneading tank reference inner volume V.sub.Tstd.

(27) Note that the supply amount M.sub.S1 of the raw material may be adjusted as appropriate with consideration given to the supply amount of a binder, the supply amount of a surfactant, and the supply amount of water.

(28) (Core Molding Method)

(29) Next, a method for molding a core according to the first embodiment will be described with reference to FIG. **4**. FIG. **4** is a flowchart showing the method for molding a core according to the first embodiment. When FIG. **4** is referred to, FIGS. **1** to **3** may also be referred to as appropriate.

(30) A raw material for a core is weighed to obtain a predetermined mass thereof from the raw material supply unit **30** (Step ST**1**). The mass of the raw material to be supplied for the first time is larger than the mass of the core to be molded, and is, for example, about twice to several times thereof.

(31) Next, a kneaded material S**2** is prepared by using the above-described weighed raw material and is supplied to the kneading tank **20** (Step ST**2**). Specifically, the kneaded material S**2** is prepared by kneading (e.g., mixing and kneading) the raw material in the kneading tank **20** by using a kneading blade(s) or the like.

(32) Next, as shown in FIGS. **1** and **2**, the kneaded material S**2** contained in the kneading tank **20** is injected into the mold **70** by the piston **50**, and a molded article S**30** is thereby molded (Step ST**3**). Note that the step ST**3** is preferably performed after the kneading tank **20** is transferred (i.e., moved) onto the mold **70**. The molded article S**30** includes a kneaded material S**31**, a molded article S**32**, and a molded article S**33**. The kneaded material S**31** remains in the kneading tank **20**. The molded article S**32** remains in the through hole **81** of the injection plate **80**. The molded article S**33** remains in the internal space **73** of the mold **70**.

(33) Next, the control unit **40** calculates the total volume change amount ΔV of the molded article S**30** after the injection, and determines the supply amount M.sub.S1 of the raw material by multiplying this calculated total volume change amount ΔV by the density ρ.sub.n of the molded core (Step ST**4**).
(34) Next, as shown in FIG. **3**, after the injection, the molded articles S**32** and S**33** are removed from the mold **70** (Step ST**5**). Specifically, after the injection, the first and second molds **71** and **72** are opened, and the molded articles S**32** and S**33** are removed the mold **70**. After the injection, the kneaded material S**31** remains in the kneading tank **20**. Further, the core can be obtained by trimming unnecessary parts from the molded article S**33**.
(35) Next, when injections have not been performed a target number of times (Step ST**6**: No), the process returns to the step ST**1**, and the raw material is weighed to obtain the predetermined mass thereof determined in the step ST**4**. On the other hand, when injections have been performed the target number of times (Step ST**6**: Yes), the continuous molding of cores is finished.
(36) As described above, according to the above-described method for molding a core, the supply amount M.sub.S1 of the raw material is obtained by using the density ρ.sub.n of the molded core after the injection and the total volume change amount ΔV of the kneaded material S**2** in the whole core molding apparatus **100** after the injection. Therefore, the change in the density of the core after the injection from the density thereof before the injection does not affect the calculation accuracy of the supply amount M.sub.S1 of the raw material for the core. Therefore, it is possible to reduce the possibility of the deterioration in the calculation accuracy of the supply amount M.sub.S1 of the raw material for the core.
(37) Further, according to the above-described method for molding a core, it is possible to calculate the total reference volume V.sub.Mstd of the kneaded material by using the volumes Vp and Vn of the kneaded material S**2** contained in the injection plate **80** and in the mold **70**, both of which can be obtained in advance, and the kneading tank reference inner volume V.sub.Tstd. Therefore, it is possible to improve the calculation accuracy of the supply amount M.sub.S1 of the raw material for the core.
(38) Further, according to the above-described method for molding a core, it is possible to calculate the total volume change amount ΔV based on the position Lpst of the piston. Therefore, it is possible to easily calculate the supply amount M.sub.S1 of the raw material for the core for each injection.
Specific Example
(39) A specific example of the core molding apparatus according to the first embodiment will be described with reference to FIG. **5**. FIG. **5** is a cross-sectional diagram of a specific example of the core molding apparatus shown in FIGS. **1** to **3**.
(40) As shown in FIG. **5**, a core molding apparatus **100***a* includes a valve **22**, a kneading blade(s) **23**, and a rotation rod **24** in addition to the components/structures of the core molding apparatus **100** shown in FIG. **1**. The core molding apparatus **100***a* includes a raw material supply unit **30***a*, which is a specific example of the raw material supply unit **30** shown in FIG. **1**.
(41) Sand S**1**, water, water glass, and/or a liquid additive(s) such as a surfactant, which are raw materials for a core, are supplied to the kneading tank **20** through the opened top thereof.
(42) For example, the valve **22** made of rubber or the like is attached to the through hole **21**. The valve **22** can prevent the raw material such as the sand S**1** supplied to the kneading tank **20** and the kneaded material S**2** from leaking from the kneading tank **20**. Meanwhile, in the central part of the valve **22**, for example, cutting having a + (plus) shape (i.e., an X-shape) in a plan view and extending through the valve (i.e., extending from the top surface to the bottom surface of the valve) in the vertical direction (the Z-axis direction) is formed. Therefore, as shown in FIGS. **1** and **2**, when a pressure is applied to the kneaded material S**2** contained in the kneading tank **20** and hence the kneaded material S**2** is injected, the cutting in the valve **22** can be opened.
(43) As shown in FIG. **5**, the kneading tank **20** is placed, for example, on a pedestal **10** having a

horizontal top surface. A projection **11**, which is engaged with the through hole **21** formed in the bottom of the kneading tank **20**, is formed on the top surface of the pedestal **10**. That is, the projection **11** of the pedestal **10** is engaged with (i.e., inserted into) the through hole **21** of the kneading tank **20**, and it supports the valve **22** attached to the through hole **21** from below. By the above-described configuration, it is possible to prevent the kneaded material S**2** from leaking from the kneading tank **20** even when the kneaded material S**2** is being kneaded.

(44) The kneaded material S**2** is obtained by kneading the raw material such as the sand S**1** supplied to the kneading tank **20** by the kneading blade **23**. The kneading blade **23** includes one or a plurality of plate-like members fixed to the rotation rod **24** extending in the vertical direction (the Z-axis direction). The directions of the normal to the plate-like members constituting the kneading blade **23** are all perpendicular to the Z-axis direction. The rotation rod **24** is connected to a driving source such as a motor (not shown), and the kneading blade **23** rotates by using the rotation rod **24** as the rotation shaft. Note that it is preferred that the central axis of the rotation rod **24** coincides with the central axis of the kneading tank **20**.

(45) Further, the kneading blade **23** can move in the vertical direction (the Z-axis direction) together with the rotation rod **24**. FIG. **5** schematically shows a state in which the kneading blade **23** is retracted upward (toward the positive side in the Z-axis) and is not rotating. The kneading blade **23** can be lowered (moved toward the negative side in the Z-axis) and can be rotated while being inserted in the kneading tank **20**.

(46) The raw material supply unit **30** includes a hopper **31**, a shutter **32**, a weighing dish **33**, a weighing meter **34**, a sand charging chute **35**, and pumps **36** to **38**.

(47) In the hopper **31**, the sand S**1** to be supplied to the kneading tank **20** is stored. An openable/closable shutter **32** is attached to a discharge port **31***a* of the hopper **31**, so that the amount of the sand S**1** charged (i.e., supplied) from the discharge port **31***a* to the weighing dish **33** can be adjusted. The opening/closing and the degree of opening of the shutter **32** are controlled by a control signal ctr**1** output from the control unit **40**.

(48) The weighing dish **33** is placed on the weighing meter **34**, and the mass of the sand S**1** charged (i.e., supplied) onto the weighing dish **33** is measured. For example, a load cell is provided inside the weighing meter **34**, and a mass signal ms representing the mass measured by the weighing meter **34**, which is an electric signal, is output to the control unit **40**. That is, the control unit **40** generates the control signal ctr**1** based on the mass signal ms, and thereby performs feedback control for the opening/closing and the degree of opening of the shutter **32**.

(49) Specifically, the control unit **40** performs control, for example, as follows. When the charging of the sand S**1** onto the weighing dish **33** is started, the control unit **40** outputs a control signal ctr**1** for opening the shutter **32** to its full width. After that, when the mass signal ms output from the weighing meter **34** gets close to a supply amount determined in advance by the control unit **40**, the control unit **40** outputs a control signal ctr**1** for reducing the degree of opening of the shutter **32**. Then, when the mass signal ms output from the weighing meter **34** reaches the supply amount determined in advance by the control unit **40**, the control unit **40** outputs a control signal ctr**1** for closing the shutter **32**.

(50) When the mass of the sand S**1** charged onto the weighing dish **33** reaches the supply amount determined in advance by the control unit **40**, for example, the weighing dish **33** is rotated around the Y-axis (i.e., is tilted), so that the sand S**1** on the weighing dish **33** is supplied to the kneading tank **20** through the sand charging chute **35**.

(51) The pumps **36** to **38** are diaphragm pumps for supplying water, water glass, and a surfactant, respectively, to the kneading tank **20**. The amount of water supplied from the pump **36** is controlled by a control signal ctr**2** output from the control unit **40**. Similarly, the amount of water glass supplied from the pump **37** is controlled by a control signal ctr**3** output from the control unit **40**. Similarly, the amount of the surfactant supplied from the pump **38** is controlled by a control signal ctr**4** output from the control unit **40**. For example, the control signals ctr**2** to ctr**4** are pulse signals,

and amounts of the water, the water glass, and the surfactant, which are determined according to the numbers of pulses of the pulse signals, are supplied from the pumps **36** to **38**, which are diaphragm pumps.
(52) After the raw material such as the sand S**1** is kneaded (e.g., mixed and kneaded) in the kneading tank **20** placed on the pedestal **10**, the kneading tank **20** containing the kneaded material S**2** is transferred (i.e., moved) from the pedestal **10** onto the mold **70**. In FIG. **5**, the kneading tank **20** on the mold **70** is indicated by two-dot chain lines.
(53) The program includes instructions (or software codes) that, when loaded into a computer, cause the computer to perform one or more of the functions described in the embodiments. The program may be stored in a non-transitory computer readable medium or a tangible storage medium. By way of example, and not a limitation, non-transitory computer readable media or tangible storage media can include a random-access memory (RAM), a read-only memory (ROM), a flash memory, a solid-state drive (SSD) or other types of memory technologies, a CD-ROM, a digital versatile disc (DVD), a Blu-ray disc or other types of optical disc storage, and magnetic cassettes, magnetic tape, magnetic disk storage or other types of magnetic storage devices. The program may be transmitted on a transitory computer readable medium or a communication medium. By way of example, and not a limitation, transitory computer readable media or communication media can include electrical, optical, acoustical, or other forms of propagated signals.
(54) Note that the present disclosure is not limited to the above-described embodiments, and they may be modified as appropriate without departing from the spirit and scope of the disclosure. Further, the present disclosure may be carried out by combining the above-described embodiments and the example thereof as appropriate.
(55) From the disclosure thus described, it will be obvious that the embodiments of the disclosure may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the disclosure, and all such modifications as would be obvious to one skilled in the art are intended for inclusion within the scope of the following claims.

Claims

1. A method for molding a core comprising: supplying a raw material that includes sand, water, water glass, and/or a liquid additive for the core to a kneading tank; kneading the raw material in the kneading tank; injecting a kneaded material made of the raw material kneaded in the kneading tank into a mold by a piston by making the kneaded material made of the raw material kneaded in the kneading tank pass through a through hole of an injection plate by the piston, and thereby molding the core by forming a molded article with a first portion of the kneaded material remaining in the kneading tank, a second portion of the kneaded material remaining in the through hole of the injection plate, and a third portion of the kneaded material remaining in an internal space of the mold; calculating an amount of a change in a total volume of the kneaded material in the kneading tank upon completion of the injection by ΔV =V.sub.p+V.sub.n−(L.sub.pst−L.sub.std)×A.sub.T, in which ΔV is the amount of the change in the total volume of the kneaded material in the kneading tank upon completion of the injection, V.sub.p is a volume of the through hole of the injection plate, V.sub.n is a volume of the mold in which the kneaded material is contained, L.sub.pst is a detected position of the piston upon completion of the injection, L.sub.std is a predetermined reference position of the piston upon completion of the injection based on a reference inner volume of the kneading tank, and A.sub.T is a cross-sectional area of the kneading tank; determining an amount of supply of the raw material by multiplying the amount of the change in the total volume by a density of a molded core measured in advance; opening the mold and removing the second portion of the molded article and the third portion of the molded article; and supplying the determined amount of supply of the raw material to the kneading tank with the first portion of the

molded article in the kneading tank, wherein the density of the molded core measured in advance and that of the kneaded material before the injection are different.