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(54) A METHOD OF USING A SEPARATOR AND A SEPARATOR

VERFAHREN ZUR VERWENDUNG EINES SEPARATORS UND SEPARATOR

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**WO-A-86/01436 WO-A-96/03214
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Description

[0001] The present invention relates to a method of using a centrifugal separator.

[0002] The invention also relates to a centrifugal separator, as known for example from WO-86/01436. Two liquids with different densities can be separated from each other by means of a centrifugal separator. A centrifugal separator can additionally be used for separating sludge and other solids from a liquid. A separator comprises a rotatable bowl, i.e. a rotor, having a stack of disks and a sludge volume for the liquid to be separated. As the bowl rotates, the solids and/or the heavier liquid, i.e. the liquid having a higher density, are transferred into the outer part, the so-called sludge volume, of the bowl under the centrifugal force, from which they are removed. The separated liquid, having a lower density, is transferred through the disk stack to the inner part of the bowl, wherefrom it is discharged from the separator.

[0003] For example, centrifugal separators in connection with piston engines in marine or power plant use are used for separating sludge and water from lubrication oil and fuel oil. The sludge separated from the oil is periodically discharged from the bowl via an outlet opening during discharge sequences. Prior to starting a discharge sequence, heavier liquid, i.e. so-called displacement water, is introduced into the bowl and the lighter liquid, i.e. oil, is displaced, whereby the removal of oil from the bowl with the sludge is prevented. The problem with separators of this type is optimizing the amount of displacement water to be introduced into the bowl. If the amount of displacement water is too small, separated oil is removed from the bowl along with the sludge. Correspondingly, if the amount of displacement water is too large, excess displacement water will be entrained with the already separated oil.

[0004] The object of the present invention is to provide a solution for optimizing the amount of displacement liquid to be introduced into a centrifugal separator.

[0005] The objects of the invention are achieved as disclosed in claims 1 and 4. In the invention, pressure of the displacement liquid introduced into the bowl is measured and the duration of the displacement liquid introduction sequence is adjusted on the basis of the pressure.

[0006] Considerable advantages are achieved by means of the invention.

[0007] In a solution according to the invention the duration of the displacement liquid introduction sequence is changed as a function of the pressure of the displacement liquid. As the amount of displacement liquid introduced into the bowl during a time unit essentially depends on the pressure of the displacement liquid, changing the duration of the introduction sequence allows introducing a constant amount of displacement liquid and thus prevent already the separated lighter liquid from being discharged from the bowl during the discharge sequence, and on the other hand it prevents mixing excess displacement liquid with the already separated lighter liquid.

[0008] In the following, the invention is disclosed in an exemplary way, by reference to the appended drawing illustrating a sectioned diagram of a centrifugal separator according to the invention.

[0009] The drawing shows a centrifugal separator 1 used for separating two liquids having different densities from each other and/or separating sludge and other solids from the liquid. There are two main types of centrifugal separators 1. One is a so-called clarifier separator, used for separating solids and sludge from liquid. The other is the so-called purifier separator used for separating heavier liquid and solids/sludge from a lighter liquid. For example, in large piston engines used as main engines of ships and power plants, the centrifugal separator 1 according to the invention can be used for separating water and/or sludge and other solids from fuel and lubrication oil from the oil. The centrifugal separator 1 can be either of the above-mentioned types.

[0010] The separator 1 comprises a rotor i.e. a bowl 2 rotatable about an axis of rotation 3. The bowl 2 comprises a body 4 inside which there is a disk stack 13 and sludge volume 6. The body 4 comprises two halves arranged against each other, a lower half 27 and an upper half 26. The lower half is pressed against the upper half by means of a force caused by the pressure of closure liquid introduced into the closure chamber 24 via line 25. The disk stack 13 and the sludge volume 6 envelope the axis of rotation 3, whereby sludge and other solids and/or liquid having higher density are transferred by centrifugal force during the rotation of the bowl 2 into the outermost volume of the bowl, the so-called sludge volume 6. Correspondingly the liquid having smaller density is transferred into the innermost part 7 of the bowl. The bowl 2 is enveloped by a stationary housing (not shown).

[0011] The separator 1 has an inlet duct, i.e. a stationary inlet tube 8 for introducing the liquid to be separated into the bowl 2. The inlet tube 8 has a pump 9 by means of which liquid is pumped into the bowl 2. The rotation speed of the pump 9 is regulated by means of a frequency converter 10. The bowl 2 comprises a disk stack 13 between the disks of which the heavier liquid and/or sludge or other solids are separated from the lighter liquid. The inlet tube 8 is located in the middle part of the bowl 2 parallel with the axis of rotation 3 and its inlet opening is on the axis of rotation 3, whereby the liquid to be separated is introduced to the lower part of the bowl 2, under the distributor 28 located under the disk stack 13. The separator 1 also has an outlet duct, i.e. a stationary discharge tube 11, for discharging the separated, i.e. lighter liquid i.e. liquid having a lower density from the bowl 2. The opening of the discharge tube 11 is located in the inner part 7 of the bowl. The discharge tube 11 is provided with a pressure sensor 12 for measuring the pressure of the separated, i.e. lighter, liquid discharged from the separator.

[0012] The outer circumference of the bowl 2 comprises openable and closable discharge openings 14 through which

sludge and other solids are removed from the bowl during the discharge sequence. The discharge openings are opened by sliding the lower half 27 downwards. The movement of the lower half 27 is provided by means of control liquid introduced to the control chamber 17 via a control liquid channel 16. The control chamber 17 comprises a discharge mechanism that allows the pressure in closure chamber 24 to be discharged via the nozzles 23 of the control chamber 17 by the influence of the pressure of the control fluid. Thus, the pressure in the bowl 5 causes the lower half 27 to slide downwards and the discharge openings open. The bowl is closed by ending the introduction of control liquid into the control chamber 17 and by adding closure liquid into the closure chamber 24. The pressure of the closure liquid will again start to have an effect in the closure chamber 24 and the lower half 27 slides back against the upper half 26 and covers the discharge openings 14.

[0013] The separator 1 is provided with a displacement liquid inlet tube 19 connected to the inlet tube 8 for introducing displacement liquid to the bowl 2 via inlet tube 8. Introduction of displacement liquid fills the bowl with a heavier liquid and thus prevents discharging the lighter liquid from the bowl via discharge openings 14 during the discharge sequence. The inlet tube 19 of displacement liquid is provided with a closure valve 20, such as an electric solenoid valve by means of which the flow of displacement liquid into the bowl can be allowed or prevented. The inlet tube 19 of the displacement liquid is provided with a pressure sensor 21 for measuring the pressure of the displacement liquid. The sensor 21 is located before the closure valve 20 in the flow direction of the displacement liquid in the displacement liquid inlet tube 19.

[0014] The separator 1 additionally comprises an electric control system 22 arranged to collect information from various measurement points, i.e. the measurement signals of the displacement liquid pressure sensor 21 and the discharge tube pressure sensor 21. The control system 22 controls the closure valve 20 on the basis of the pressure measurement of the displacement liquid. The control system 22 adjusts the opening time of the closure valve 20 i.e. the introduction time of displacement liquid into the bowl 2 on the basis of the measurement data from the pressure sensor 21. The displacement liquid introduction volume is thus kept constant or nearly constant during the introduction sequence.

[0015] In addition to this, the control system 22 is provided with information about the control frequency or output frequency of the frequency converter 10, the frequencies being at least nearly relative to the rotation speed of the pump 9, and the measurement signal of the pressure sensor of the discharge tube 12. The control system 22 adjusts the length of the alarm delay after the discharge sequence on the basis of the rotation speed of the pump 9. An alarm is triggered if after the discharge sequence, during an alarm delay subsequent to the beginning of the separation, there is no signal indicating sufficient pressure from the pressure sensor of the discharge tube 12, i.e. there is no liquid flow at all in the discharge tube or the pressure of the liquid is too low.

[0016] The bowl 2 is rotated about the axis of rotation 3 during the operation of the centrifugal separator 1. The liquid to be separated is pumped with a pump 9 via inlet tube 8 to the bowl 2. The flow of the liquid introduced into the bowl 2 is adjusted to be suitable by changing the rotation speed of the pump 9 by means of a frequency converter 10. The control system 22 changes the output frequency of the frequency converter 10, i.e. in practice the rotation speed of the pump 9 on the basis of the need at the target application of the separated liquid. In the bowl 2 the heavier liquid, i.e. liquid with a higher density, and/or sludge and other solids are transferred to the outer part of the bowl, i.e. the sludge volume 6. The lighter liquid, i.e. liquid with a lower density, is transferred through the disk stack 13 into the inner part 7. In a purifier type separator the heavier liquid is continuously discharged from the outer part 6 via a so-called gravity disc (not shown).

[0017] Separated, i.e. lighter, liquid is removed from the bowl 2 via discharge tube 11. Heavier liquid and/or sludge and solids are discharged from the sludge volume 6 of the bowl periodically via discharge openings 14. Prior to beginning of the discharge sequence the introduction of the liquid to be separated to the bowl 2 via the inlet channel 8 is stopped. Subsequent to this, the closure valve 20 is opened and the introduction of displacement liquid to the bowl 2 is started. The density of the displacement liquid is higher than that of the separated liquid. Usually the displacement liquid is the same as the heavier liquid in the sludge volume 6 of the bowl, typically water. Due to the introduction of the displacement liquid the amount of the heavier liquid in the bowl 2 is increased, whereby the interface 29 between the lighter and the heavier liquid moves towards the inner part 7 of the bowl.

[0018] If too small an amount of displacement liquid is introduced into the bowl 2 during the introduction sequence, separated liquid is discharged from the bowl via discharge openings 14 during the discharge sequence. On the other hand, if the amount of introduced displacement liquid is too high, displacement liquid is mixed with the separated liquid. A suitable introduction amount of displacement liquid can be defined, for example, by testing or on the basis of the properties of the liquid to be separated. In order to optimize the introduction amount of the displacement liquid the duration of the introduction sequence is adjusted on the basis of the pressure of the displacement liquid. The pressure of the displacement liquid is measured in the displacement liquid introduction tube by means of measuring device 21 and the measurement signal is directed to the control system 22. The control system 22 defines the duration of the introduction sequence on the basis of the measured pressure of the displacement liquid and controls the closure valve 20 correspondingly. The aim is to maintain a constant or essentially constant amount of displacement liquid being introduced into the bowl during the introduction sequence. For example, if the pressure of the displacement liquid is 6 bar, the duration of the introduction sequence is adjusted to 4 seconds. Correspondingly, if the pressure of the displace-

ment liquid is 2 bar, the length of the introduction sequence is 7 seconds.

[0019] At the beginning of the discharge period or before the beginning of the discharge period the introduction of the displacement liquid is stopped by closing the closure valve 20. Control liquid is introduced into the control chamber 17 via control channel 16. Due to the hydraulic pressure in the control chamber 17 the lower half of the bowl is displaced from its place, revealing the discharge openings 14. The heavier liquid and sludge are discharged from the bowl via discharge openings 14 to the housing enveloping the bowl. The aim is to provide as small as possible loss of the lighter, separated liquid, usually oil, during the discharge of the bowl. As the discharge sequence ends, the introduction of control liquid is stopped and the hydraulic pressure in the control chamber 17 is discharged via nozzles 23. Subsequent to this, closure liquid is introduced under the lower half 26 of the bowl into the chamber 24, whereby the lower half 27 moves upwards and again covers the discharge openings 14 and the discharge sequence ends. The length of the discharge sequence is about one second or some seconds, if the introduction of control liquid and closure liquid are controlled by different solenoid valves. However, in modern separators the same control liquid both opens and closes using channel arrangements inside the bowl in less than a second, even in a fraction of a second. When the discharge sequence has ended, the introduction of the liquid to be separated into the bowl 2 via inlet tube 8 is again started. In a purifier type separator so-called sealing liquid is introduced into the bowl 2 after the discharge sequence via the displacement liquid inlet tube 19 and the inlet tube 8 before starting the introduction of the liquid to be separated.

[0020] The adjustment of the duration of the displacement liquid introduction sequence can be carried out as an adjustment taking place as a function of a continuous measurement. For example, as the closure valve 20 opens, the pressure of the displacement liquid in the displacement liquid inlet tube 19 decreases. The pressure of the displacement liquid in the inlet tube 19 is continuously measured during the introduction sequence and the control system 22 continuously defines a new value for the duration of the introduction sequence on the basis of the average pressure during the introduction sequence. When the duration of the displacement liquid introduction sequence defined on the basis of the average pressure is reached, the control system 22 closes the closure valve 20 and the introduction of displacement liquid into the bowl 2 ends. In this embodiment it is also desirable to maintain the amount of displacement liquid introduced into the bowl 2 constant or essentially constant during the introduction sequence regardless of pressure changes.

[0021] The adjustment of the duration of the displacement liquid introduction sequence can also be carried out by calculating the volume flow of the displacement liquid with the Bernoulli equation. In this case there is a throttle or other point having a different cross-sectional flow area with a pressure sensor in the inlet tube of the displacement liquid. The pressure measurements of the inlet tube 19 and the throttle allow calculating the volume flow of the liquid flowing in the inlet tube 19 of the displacement liquid by using Bernoulli's equation and continuity equation, when the measurement points of pressure are at the same height.

[0022] Bernoulli's equation:

$$p_1 + \frac{v_1^2}{2} \rho = p_2 + \frac{v_2^2}{2} \rho$$

continuity equation:

$$Q = v_1 A_1 = v_2 A_2$$

[0023] From these, the volume flow of the displacement liquid is calculated as:

$$Q_1 = A_1 * \sqrt{2 * (p_2 - p_1) / (\rho * (1 - (A_1 / A_2)^2))},$$

In which

Q_1 volume flow in the displacement liquid inlet tube, m³/s

v_1 = flow velocity in the displacement liquid inlet tube, m/s

v_2 = flow velocity at the throttle of the displacement liquid, m/s

p_1 = the pressure of the displacement liquid in the displacement liquid inlet tube, N/m²

p_2 = the pressure of the displacement liquid at the throttle, N/m²

ρ = density of the displacement liquid, kg/m³

A_1 = cross-sectional flow area in the displacement liquid inlet tube, m²

A_2 = cross-sectional flow area at the throttle, m²

[0024] The flow speed can be used for determining the volume flow of the displacement liquid by using the cross-sectional flow area of the displacement liquid inlet tube.

[0025] The control system 22 defines the duration of the introduction sequence on the basis of the throttle of the water volume flowing the displacement liquid inlet tube 19 and the pressure measurements of the inlet tube 19 and controls the closure valve so that the amount of water introduced into the bowl during the introduction duration of the displacement liquid is as desired. In this embodiment it is also desirable to maintain the amount of displacement liquid introduced into the bowl constant or essentially constant during the introduction sequence regardless of pressure changes. By using the volume flow calculated with Bernoulli's equation the correct opening time is calculated continuously for the displacement water valve 20.

[0026] The control system 22 also changes the length of the alarm delay as a function of the volume flow of the liquid to be separated introduced into the separator. The alarm delay starts when separating is started again after the discharge sequence has ended. In case the pressure of the separated liquid in discharge tube 11 is less than a predetermined limit value after the alarm delay, an alarm is triggered. The pressure of the separated liquid is measured by means of a pressure sensor 12 and the control system 22 triggers an alarm in case the signal from the pressure sensor 12 indicates the pressure in the discharge tube 11 to be less than a predetermined limit value after the alarm delay. Too low a pressure in the discharge tube 11 after the alarm delay can mean a malfunction of the separator, such the discharge openings 14 having not closed. The alarm limit of pressure can be, for example, the same as the minimum pressure required by the target application of the separated liquid. The rotation speed of the pump 9 has an effect on the speed at which the pressure in the discharge tube 11 returns to its normal level after the discharge sequence of the separation chamber 5. With a lower rotation speed the separator fills and the pressure returns slower than with a higher speed.

[0027] The length of the alarm delay is adjusted on the basis of the volume flow of the liquid to be separated introduced into the separator. The volume flow of the liquid to be separated can be defined with, for example, a measurement apparatus suitable for the purpose or on the basis of the rotation speed of the pump 9 or on the basis of the output frequency or control frequency of the frequency converter 10. When the volume flow is smaller, the alarm delay is longer than with a larger volume flow. The control system 22 adjusts the length of the alarm delay. For example, when the pump rotates at a speed corresponding to a frequency converter output frequency of 50 Hz, the length of the alarm delay is 10 seconds. If the rotation speed of the pump 9 changes to correspond with a frequency converter output frequency of 15 Hz, the control system 22 changes the length of the alarm delay to 40 seconds. The alarm can be, for example, a message displayed on screen in the control room and/or the control system 22 can cut the introduction of the liquid to be separated into the separator.

[0028] Subsequent to the discharge sequence the duration of the sealing liquid introduction sequence (purifier separator) can be defined using the pressure measurement of the sealing liquid with methods similar to those used for defining the length of the displacement liquid introduction sequence. The same methods can also be used for defining the durations of the introduction sequences of control liquid and closure liquid.

Claims

1. A method of using a centrifugal separator (1), the centrifugal separator comprising a bowl (2) for the liquid to be separated, in which method the liquid to be separated is introduced into the bowl (2), separated liquid is discharged from the inner part (7) of the bowl, sludge is periodically discharged from the outer part (6) of the bowl during discharge sequences, and displacement liquid is introduced into the bowl (2) during displacement liquid introduction sequence prior to beginning the discharge sequence, **characterized in that** the pressure of the displacement liquid introduced into the bowl (2) is measured, and the duration of the displacement liquid introduction sequence is adjusted on the basis of the pressure of the displacement liquid.
2. A method according to claim 1, **characterized in that** the pressure of the displacement liquid introduced into the bowl (2) is continuously measured during the introduction sequence, the average pressure during the introduction sequence is continuously determined, and the duration of the displacement liquid introduction sequence is adjusted on the basis of the average pressure of the displacement liquid.
3. A method according to claim 1 or 2, **characterized in that** the pressure of the displacement liquid introduced into the bowl (2) is measured in two points having different cross-sectional flow areas, the volume flow of the displacement liquid introduced into the bowl (2) is determined on the basis of the pressure measurements, and the duration of the discharge sequence is adjusted on the basis of the volume flow.
4. A centrifugal separator (1) comprising a bowl (2) for the liquid to be separated, an inlet duct (8) for introducing the liquid to be separated into the bowl (2), an outlet duct (11) for discharging separated liquid from the inner part (7)

of the bowl, openable and closable discharge openings (14) for periodically removing sludge from the outer part (6) of the bowl during discharge sequences, and a displacement liquid inlet duct (19) for introducing displacement liquid into the bowl (2), the inlet duct (19) being provided with a closure means (20) for controlling the introduction of the displacement liquid, **characterized by** a measuring device (21) arranged in connection with the displacement liquid inlet duct (19) for measuring the pressure of the displacement liquid, and a control system (22) arranged to control the closure means (20) on the basis of the pressure of the displacement liquid.

Patentansprüche

1. Verfahren zur Verwendung eines Zentrifugalseparators (1), wobei der Zentrifugalseparator eine Schale (2) für die abzuscheidende Flüssigkeit umfasst, wobei bei diesem Verfahren die abzuscheidende Flüssigkeit in die Schale (2) eingeleitet wird, abgeschiedene Flüssigkeit aus dem Innenteil (7) der Schale abgeleitet wird, Schlamm während Ableitungssequenzen periodisch aus dem Außenteil (6) der Schüssel abgeleitet wird und Verdrängungsflüssigkeit während der Verdrängungsflüssigkeit-Einleitungssequenz vor Beginn der Ableitungssequenz in die Schale (2) eingeleitet wird, **dadurch gekennzeichnet, dass** der Druck der in die Schale (2) eingeleiteten Verdrängungsflüssigkeit gemessen wird und die Dauer der Verdrängungsflüssigkeit-Einleitungssequenz auf der Grundlage des Drucks der Verdrängungsflüssigkeit angepasst wird.
2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** der Druck der in die Schale (2) eingeleiteten Verdrängungsflüssigkeit während der Einleitungssequenz kontinuierlich gemessen wird, der mittlere Druck während der Einleitungssequenz kontinuierlich gemessen wird und die Dauer der Verdrängungsflüssigkeit-Einleitungssequenz auf der Grundlage des mittleren Drucks der Verdrängungsflüssigkeit angepasst wird.
3. Verfahren nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** der Druck der in die Schale (2) eingeleiteten Verdrängungsflüssigkeit an zwei Stellen, die unterschiedliche Strömungsquerschnittsbereiche aufweisen, gemessen wird, der Volumenstrom der in die Schale (2) eingeleiteten Verdrängungsflüssigkeit auf Grundlage der Druckmessungen bestimmt wird, und die Dauer der Ableitungssequenz auf der Grundlage des Volumenstroms angepasst wird.
4. Zentrifugalseparator (1), der eine Schale (2) für die abzuscheidende Flüssigkeit, einen Einlasskanal (8) zum Einleiten der abzuscheidenden Flüssigkeit in die Schale (2), einen Ableitungskanal (11) zum Ableiten abgeschiedener Flüssigkeit aus dem Innenteil (7) der Schale, öffnbare und schließbare Ableitungsöffnungen (14) zum periodischen Entfernen von Schlamm während Ableitungssequenzen aus dem Außenteil (6) der Schale und einen Verdrängungsflüssigkeit-Einlasskanal (19) zum Einleiten von Verdrängungsflüssigkeit in die Schale (2) umfasst, wobei der Einlasskanal (19) mit Verschlussmitteln (20) zum Steuern der Einleitung der Verdrängungsflüssigkeit versehen ist, **gekennzeichnet durch** eine Messvorrichtung (21), die zum Messen des Drucks der Verdrängungsflüssigkeit in Verbindung mit dem Verdrängungsflüssigkeit-Einlasskanal (19) angeordnet ist, und ein Steuersystem (22), das dafür ausgelegt ist, die Verschlussmittel (20) auf der Grundlage des Drucks der Verdrängungsflüssigkeit zu steuern.

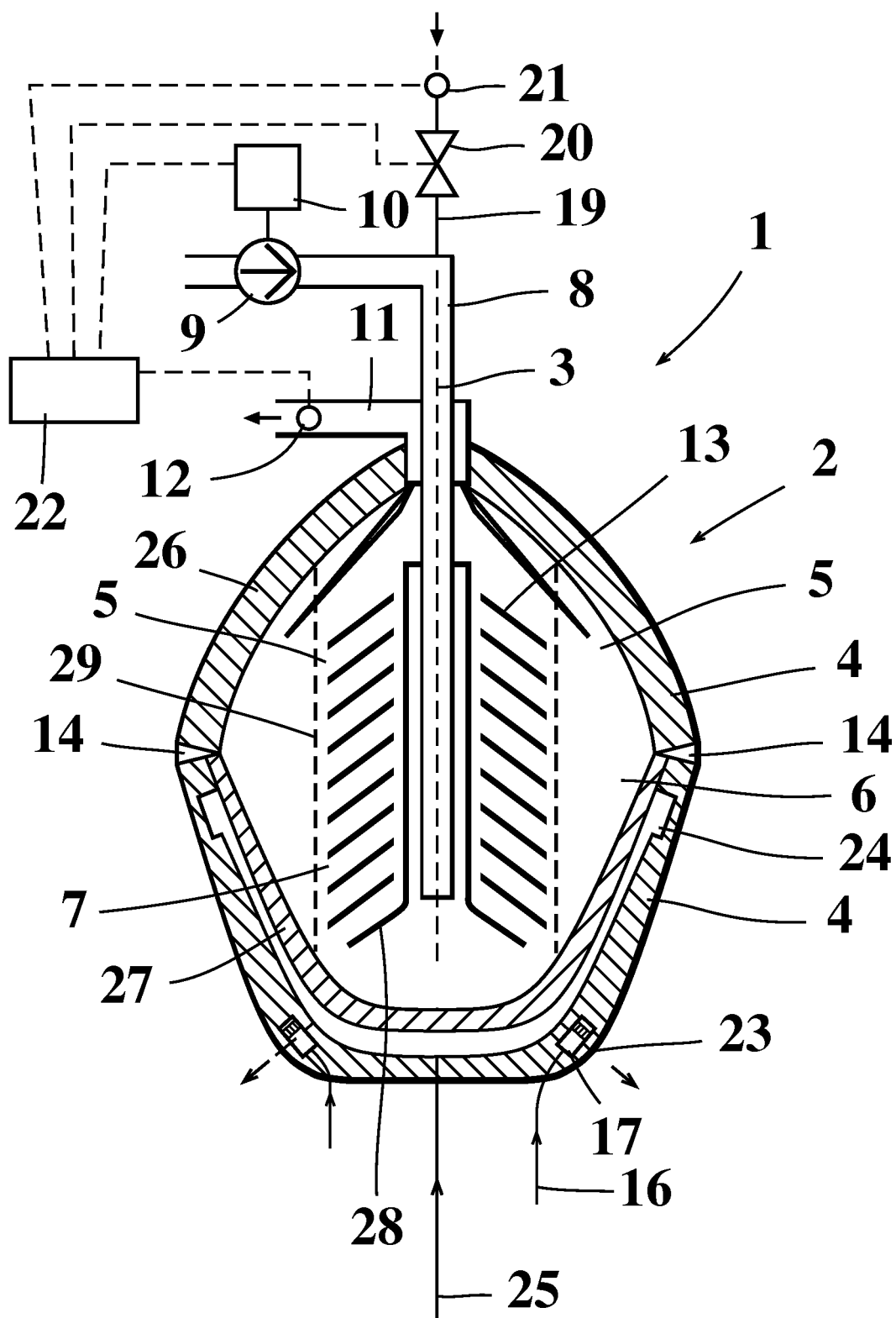
Revendications

1. Procédé d'utilisation d'un séparateur centrifuge (1), le séparateur centrifuge comprenant une cuve (2) pour le liquide à séparer, dans lequel procédé le liquide à séparer est introduit dans la cuve (2), le liquide séparé étant évacué de la partie intérieure (7) de la cuve, de la boue étant périodiquement évacuée de la partie extérieure (6) de la cuve pendant des séquences d'évacuation, et du liquide de déplacement étant introduit dans la cuve (2) pendant une séquence d'introduction de liquide de déplacement avant de commencer la séquence d'évacuation, **caractérisé en ce que** la pression du liquide de déplacement introduit dans la cuve (2) est mesurée, et **en ce que** la durée de la séquence d'introduction de liquide de déplacement est ajustée sur la base de la pression du liquide de déplacement.
2. Procédé selon la revendication 1, **caractérisé en ce que** la pression du liquide de déplacement introduit dans la cuve (2) est mesurée en continu pendant la séquence d'introduction, la pression moyenne pendant la séquence d'introduction étant déterminée en continu, et la durée de la séquence d'introduction de liquide de déplacement étant ajustée sur la base de la pression moyenne du liquide de déplacement.
3. Procédé selon la revendication 1 ou 2, **caractérisé en ce que** la pression du liquide de déplacement introduit dans

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la cuve (2) est mesurée en deux points ayant différentes aires de section de flux, le flux volumique du liquide de déplacement introduit dans la cuve (2) étant déterminé sur la base des mesures de pression, et la durée de la séquence d'évacuation étant ajustée sur la base du flux volumique.

- 5 4. Séparateur centrifuge (1) comprenant une cuve (2) pour le liquide à séparer, un conduit d'entrée (8) pour introduire le liquide à séparer dans la cuve (2), un conduit de sortie (11) pour évacuer le liquide séparé de la partie intérieure (7) de la cuve, des ouvertures d'évacuation pouvant être ouvertes et fermées (14) pour périodiquement enlever de la boue de la partie extérieure (6) de la cuve pendant les séquences d'évacuation, et un conduit d'entrée de liquide de déplacement (19) pour introduire du liquide de déplacement dans la cuve (2), le conduit d'entrée (19) étant doté d'un moyen de fermeture (20) pour contrôler l'introduction du liquide de déplacement,
- 10 **caractérisé par** un dispositif de mesure (21) disposé en connexion avec le conduit d'entrée de liquide de déplacement (19) pour mesurer la pression du liquide de déplacement, et un système de commande (22) étudié pour commander le moyen de fermeture (20) sur la base de la pression du liquide de déplacement.



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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