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(54) **A CENTRIFUGAL SEPARATOR**

(57) The present invention provides a centrifugal separator for separating at least a liquid heavy phase from a liquid feed mixture, comprising a frame (2), a drive member (3) and a rotatable part (4), wherein the drive member (3) is configured to rotate the rotatable part (4) in relation to the frame (2) around an axis of rotation (X), and wherein the rotatable part (4) comprises a centrifuge bowl (5) enclosing a separation space (9a) and a sludge space (9b). Further, the separation space (9a) comprises a stack (10) of separation discs (40) arranged coaxially around the axis of rotation (X) and wherein said sludge space (9b) is arranged radially outside said stack (10) of separation discs (40). The centrifuge bowl (5) further comprises an inlet (14) for receiving the liquid feed mixture and a first outlet chamber (6) in fluid connection with a heavy phase outlet pipe (6a) for discharging a separated liquid heavy phase. The centrifugal separator (1) further comprises a plurality of outlet pipes (30) for transport of said separated liquid heavy phase from said sludge space (9b) towards said first outlet chamber (6); and wherein the stack (10) of separation discs is compressed with a compression force when mounted in the centrifuge bowl (5) and wherein said plurality of outlet pipes (30) form an element for transmitting said compression force to the compressed stack (10) of separation discs.

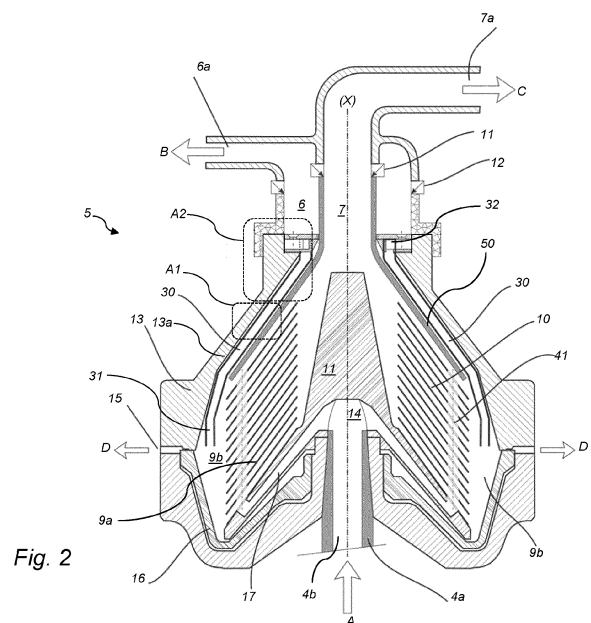


Fig. 2

Description

Field of the Invention

[0001] The present invention relates to the field of centrifugal separators, and more a centrifugal separator for separating at least on liquid heavy phase from a liquid feed mixture.

Background of the Invention

[0002] Centrifugal separators are generally used for separation of liquids and/or for separation of solids from a liquid. During operation, liquid mixture to be separated is introduced into a rotating bowl and heavy particles or denser liquid, usually water, accumulates at the periphery of the rotating bowl whereas less dense liquid accumulates closer to the central axis of rotation. This allows for collection of the separated fractions, e.g. by means of different outlets arranged at the periphery and close to the rotational axis, respectively.

[0003] In a centrifugal separator for clarification of beer, which has a sludge space where the separated heavy phase comprising yeast is collected, the yeast is usually ejected through discharges by intermittently opening outlets in the periphery of the separator bowl while the clarified beer is leaving the centrifugal separator through a liquid light phase outlet.

[0004] A centrifugal separator for clarification of beer is disclosed in WO2021058287, in which the yeast concentrate is flowing into a set of outlet pipes from a position close to the periphery in the sludge space to a liquid heavy phase outlet. Such yeast cells leaving the centrifugal separator by the liquid heavy phase outlet have a high probability to survive the centrifugation and may be used for the next brewing batch, while much of the yeast cells that are ejected at the intermittent discharges are dead and are not usable in further fermentation.

[0005] However, in such types of separators, there may be a problem of securing the position of the outlet pipes during operation of the centrifugal separator. Such pipes experience large centrifugal forces and the position may be altered and the pipes may shatter e.g. during an intermittent discharge of a separated sludge phase from the centrifuge bowl.

Summary of the Invention

[0006] It is an object of the invention to at least partly overcome one or more limitations of the prior art. In particular, it is an object to provide a centrifugal separator having an improved fixation of outlet pipes for continuous discharge of a separated liquid heavy phase.

[0007] As a first aspect of the invention, there is provided a centrifugal separator for separating at least a liquid heavy phase from a liquid feed mixture, comprising

a frame, a drive member and a rotatable part,

wherein the drive member is configured to rotate the rotatable part in relation to the frame around an axis of rotation (X), and

wherein the rotatable part comprises a centrifuge bowl enclosing a separation space and a sludge space;

wherein the separation space comprises a stack of separation discs arranged coaxially around the axis of rotation (X) and wherein the sludge space is arranged radially outside the stack of separation discs; wherein the centrifuge bowl further comprises an inlet for receiving the liquid feed mixture and a first outlet chamber in fluid connection with a heavy phase outlet pipe for discharging a separated liquid heavy phase,

and wherein the centrifugal separator further comprises a plurality of outlet pipes for transport of the separated liquid heavy phase from the sludge space towards the first outlet chamber; and wherein the stack of separation discs is compressed with a compression force when mounted in the centrifuge bowl and wherein the plurality of outlet pipes form an element for transmitting the compression force to the compressed stack of separation discs.

[0008] As used herein, the term "axially" denotes a direction which is parallel to the rotational axis (X). Accordingly, relative terms such as "above", "upper", "top", "below", "lower", and "bottom" refer to relative positions along the rotational axis (X). Correspondingly, the term "radially" denotes a direction extending radially from the rotational axis (X). A "radially inner position" thus refers to a position closer to the rotational axis (X) compared to "a radially outer position".

[0009] The plurality of outlet pipes for transport of the separated liquid heavy phase from the sludge space towards the first outlet chamber may be arranged for continuous removal of a liquid heavy phase from the sludge space. Moreover, the plurality of outlet pipes may be equidistantly arranged around the axis of rotation (X).

[0010] Upon assembling of a centrifugal separator of this kind, the separation discs are stacked upon each other on e.g. a distributor, whereafter they are compressed axially by being squeezed together by a force exerted from i.a. the upper portion of the bowl hood. The first aspect of the invention is based on the insight that if the plurality of outlet pipes from an element for transmitting the compression force to the compressed stack of separation discs, also the plurality of outlet pipes are held tightly in place, thereby decreasing the risk of displacement during operation of the centrifugal separator. The compression force may thus mainly be an axial compression force. Thus, the plurality of outlet pipes form a portion of the parts of the centrifugal separator used for transmitting a compression force when compressing the disc stack when the centrifuge bowl is mounted, i.e. the plurality of outlet pipes form a load bearing element for the axial compression force.

[0011] The centrifugal separator is for separation of a liquid feed mixture. The liquid feed mixture may be an aqueous liquid or an oily liquid. As an example, the centrifugal separator may be for separating a sludge phase and a liquid heavy phase and potentially also another liquid phase- a liquid light phase - from the liquid feed mixture. The liquid heavy phase has a density that is higher than the density of the light phase. The liquid mixture may for example be a liquid feed mixture comprising yeast cells used in a brewing process.

[0012] The frame of the centrifugal separator is a non-rotating part, and the rotatable part may be supported by the frame by at least one bearing device. The rotatable part of the separator may be arranged to be rotated around vertical axis of rotation, i.e. the axis of rotation (X) may extend vertically. The rotatable part comprises a centrifuge bowl. The centrifuge bowl is usually supported by a spindle, i.e. a rotatable shaft, and may thus be mounted to rotate with the spindle. Consequently, the rotatable part may comprise a spindle that is rotatable around the axis of rotation (X). The centrifugal separator may be arranged such that the centrifuge bowl is supported by the spindle at one of its ends, such as at the bottom end or the top end of the spindle.

[0013] The drive member for rotating the rotatable part of the separator may comprise an electrical motor having a rotor and a stator. The rotor may be fixedly connected to the rotatable part, such as to a spindle. Alternatively, the drive member may be provided beside the spindle and rotate the rotatable part by a suitable transmission, such as a belt or a gear transmission.

[0014] The centrifuge bowl encloses by its walls a separation space and a sludge space. The separation space, in which the separation of the liquid feed mixture takes place, comprises a stack of separation discs. The separation discs may e.g. be of metal. Further, the separation discs may be frustoconical separation discs, i.e. having separation surfaces forming frustoconical portions of the separation discs. Radially outside of the stack of separation discs is the sludge space, in which separated sludge and liquid heavy phase is collected during operation. The sludge space thus extends radially from the outer portion of the stack of separation discs to the inner wall of the centrifuge bowl.

[0015] The separation discs are arranged coaxially around the axis of rotation (X) at a distance from each other to form passages between each two adjacent separation discs. The stack of separation discs thus forms a surface enlarging insert that increases the separation efficiency as liquid mixture flows in the passages of the stack. In embodiments of the first aspect, the stack of separation discs comprises more than 200 separation discs. For example, the stack of separation discs may have a diameter that is more than 300 mm and a thickness that is less than 0.40 mm, such as less than 0.30 mm.

[0016] The centrifugal separator also comprises an inlet for receiving the liquid mixture to be separated (the

liquid feed mixture). This inlet may be arranged centrally in the centrifuge bowl, thus at rotational axis (X). The centrifugal separator may be arranged to be fed from the bottom, such as through a spindle, so that the liquid feed mixture is delivered to the inlet from the bottom of the separator. Alternatively, the centrifugal separator may be arranged to be fed from the top, through a stationary inlet pipe extending into the centrifuge bowl to the inlet.

[0017] Further, the centrifugal separator comprises outlets for the separated phases. The centrifuge bowl comprises a first outlet chamber which is in fluid connection with a heavy phase outlet pipe for discharging a separated liquid heavy phase. The outlet pipe is thus a stationary outlet pipe. In analogy, if also a liquid light phase is to be separated, the centrifuge bowl may comprise a second outlet chamber which is in fluid connection with a light phase outlet pipe for discharge of a separated liquid light phase. Also such outlet pipe is a stationary outlet pipe. Thus, the centrifugal separator may further comprise a light phase outlet pipe for discharging a separated liquid light phase.

[0018] Consequently, in embodiments of the first aspect, the centrifugal separator is arranged for separating a liquid heavy phase and a liquid light phase from the liquid feed mixture, and wherein the centrifugal separator further comprises a light phase outlet pipe for discharging a separated liquid light phase. The liquid light phase has a density that is lower than the density of the liquid heavy phase.

[0019] The first and second outlet chambers may be arranged on the upper portion of the centrifuge bowl.

[0020] The outlet chamber or chambers may be sealed to the liquid outlet pipes by means of e.g. a mechanical seal or a liquid seal. The seal may be a hermetic seal, such as a mechanical hermetic seal, used when the material to be separated in the centrifugal separator must not be exposed to or come in contact with the atmosphere. Thus, a hermetic seal reduces the risk of any substance, such as oxygen, or particle in the atmosphere from contaminating the liquid feed or a separated phase. With a mechanical hermetic seal, there are no air-pockets during operation and control of the liquid interface position in the centrifuge bowl may be achieved by altering the backpressures/flow rate of the liquid phases. This may be performed by one mechanical seal arranged at the top of the centrifuge bowl. The mechanical seal may be a double mechanical seal, i.e. comprising a rotatable portion and a stationary portion forming the sealing interface therebetween.

[0021] Also the inlet may be sealed by a hermetic seal, such as a mechanical hermetic seal.

[0022] Further, the centrifugal separator may comprise a sludge outlet for a separated sludge phase. The sludge phase comprises a solids fraction. In embodiments of the first aspect, the sludge outlet is in the form of a set of intermittently openable outlets arranged at the periphery of the centrifuge bowl. The intermittently openable outlets may be equidistantly spaced around the axis of rotation

(X). As an alternative, the sludge outlets may be nozzles arranged for continuous discharge of a separated sludge phase.

[0023] Consequently, in embodiments of the first aspect, the centrifugal separator is comprising sludge outlets at the periphery of the centrifuge bowl. The sludge outlets may be in the form of a set of intermittently openable outlets.

[0024] In embodiments of the first aspect, the stack of separation discs is arranged below a top disc, and the plurality of outlet pipes are arranged between the top disc and the upper bowl hood of the centrifuge bowl.

[0025] The top disc may also be an element for transmitting the compression force to the compressed stack of separation discs. The top disc may be thicker than the separation discs of the disc stack. Further, the top disc may have a diameter that is larger than the diameter of the separation discs of the disc stack.

[0026] If the plurality of outlet pipes are arranged between the top disc and the upper bowl hood of the centrifuge bowl, the plurality of pipes may be in contact with the top disc and/or the inner surface of the upper bowl hood of the centrifuge bowl.

[0027] When arranged on the top disc, the plurality of outlet pipes thus function as load bearing elements on the upper surface of the top disc, i.e. taking up axial compression forces from the upper bowl hood.

[0028] Moreover, the plurality of outlet pipes may have their inlet end portions arranged in the sludge space such that the inlet end portions are arranged a distance from the surrounding inner wall of the centrifuge bowl in the sludge space.

[0029] As an example, the top disc may be free of further load bearing elements on its upper surface.

[0030] A traditional prior art top disc usually has wings as load bearing elements. According to the present invention, such "wings" may instead be used as the pipes or channels for transporting a liquid heavy phase from the sludge space towards the first outlet chamber. Thus, if the plurality of outlet pipes form an element for transmitting the compression force to the compressed stack of separation discs, the top disc may be formed as a less complex element with a decreased amount of material.

[0031] In embodiments of the first aspect, the plurality of outlet pipes are arranged within the stack of separation discs.

[0032] Thus, the plurality of outlet pipes do not need to be arranged above the top disc but may instead be arranged axially within the stack of separation discs, such that it has some separation discs axially below and some separation discs axially above. Preferably, the plurality of outlet pipes are arranged within the upper half, such as within the upper 25 % of the separation discs. As an example, the plurality of outlet pipes may be arranged such that less than 20 separation discs are arranged above the pipes.

[0033] In embodiments of the first aspect, the centrifugal separator is further comprising an annular seal

member extending around the axis of rotation (X) and wherein the plurality of outlet pipes extend through the annular seal member.

[0034] The annular seal member may be ring formed with a central through hole, thus having an inner periphery and an outer periphery further. Moreover, the annular seal member may have a sealing lip on the inner periphery to ensure a good sealing function.

[0035] Further, the annular seal member may comprise a plurality of through holes, one for each of the plurality of outlet pipes. When the pipes are arranged within the through holes, they may be evenly distributed around the axis of rotation (X).

[0036] The annular seal member may be of a polymeric material, such as rubber.

[0037] Having an annular seal member as a single element that seals all the plurality of outlet pipes may also aid in securing the position of the plurality of outlet pipes.

[0038] As an example, the annular seal member may seal a space for the separated liquid light phase.

[0039] The space for the separated liquid light phase may be arranged radially inside the stack of separation discs. Further, such space may be a channel for transporting separated liquid light phase towards a second outlet chamber that is in fluid connection with a light phase outlet pipe.

[0040] As an example, the annular seal member may seal between a space for the separated liquid light phase and a space between the plurality of outlet pipes.

[0041] Thus, the annular seal member may be arranged for sealing a separated liquid light phase from e.g. liquid heavy phase that may be present in between the plurality of outlet pipes.

[0042] Furthermore, the annular seal member may further be arranged to seal between the first outlet chamber and a space between the plurality of outlet pipes.

[0043] Consequently, the annular seal member may have two purposes. First, sealing the liquid light phase from being contaminated by separated liquid heavy phase that may be present between the plurality of outlet pipes. Further, the annular seal member may also seal the first outlet chamber from the space between the plurality of outlet pipes, thereby securing and securing that only liquid heavy phase from the position of the pipes in the sludge space is transferred to the first outlet chamber, i.e. that only liquid heavy phase that is transferred through the plurality of pipes is discharged via the heavy phase outlet pipe of the separator.

[0044] Moreover, the stack of separation discs may be arranged below a top disc and the annular seal member may be arranged axially above the top disc. The top disc may be as discussed herein above. The annular seal member may be in contact with the top disc. Thus, the annular seal member may be arranged above the top disc, such as sealing against an upper portion of the top disc.

[0045] In embodiments of the first aspect, the centrifugal separator further comprises an annular guide mem-

ber for positioning the upper portions of the plurality of outlet pipes. The annular guide member comprises channels through which the outlet pipes extend. Further, an upper portion of the centrifuge bowl may be fastened to such annular guide member via at least one screw member.

[0046] If the upper portion of the centrifuge bowl is fastened to such annular guide member, the guide member helps in sealing against the upper portion of the bowl. Such an annular guide member may further aid in positioning the first outlet chamber for the separated liquid heavy phase. Moreover, an annular guide member according to this embodiment may also aid in sealing between the separated liquid phases together with the annular seal member discussed above. The centrifugal separator may also be provided with a number of vortex nozzles arranged in vortex chambers at the outlet end portions of the plurality of outlet pipes (as described in WO2021058287A1). The position of such vortex chambers may be stabilized by the annular guide member.

[0047] The upper portions of the plurality of outlet pipes may be the radially inner portions. As an example, the upper portions may be in direct contact with the first outlet chamber. The annular guide member may thus be arranged under the upper portion of the centrifuge bowl, thus under the bowl hood, and may i.a. be used for securing the upper portion of the centrifuge bowl hood and further securing the position of the plurality of outlet pipes. If an annular seal member is used as described above, such seal member may seal the channels of the guide member through which the plurality of outlet pipes extend.

[0048] As a second aspect of the invention, there is provided a method of separating at least a liquid heavy phase from a liquid feed mixture, comprising the steps of

- a) introducing the liquid feed mixture into a centrifugal separator according to the first aspect above; and
- b) discharging a separated liquid heavy phase from the centrifugal separator.

[0049] This aspect may generally present the same or corresponding advantages as the former aspect. Effects and features of this second aspect are largely analogous to those described above in connection with the first aspect. Embodiments mentioned in relation to the first aspect are largely compatible with the second aspect of the invention.

[0050] As discussed in relation to the first aspect above, the liquid feed mixture may comprise solids that are separated into a sludge phase. Consequently, in embodiments of the second aspect, the method further comprises the step of:

c) discharging a separated sludge phase from the centrifugal separator.

[0051] Such a step c) may comprise intermittently ejecting the separated solids phase through a set of intermittently openable outlets.

[0052] Further, if more than one liquid phase is separated in the centrifugal separator, the method also comprises a step of:

d) discharging a separated liquid light phase from the centrifugal separator

[0053] The inventive concept disclosed herein may be used when separating a variety of different feed mixtures. Especially, the inventive concept may be used when separating a liquid feed mixture comprising yeast, since the yeast may be discharged more gently, i.e. with a higher survival rate, via the plurality of outlet conduits in the liquid heavy phase. Thus, in embodiments, the liquid feed mixture comprises yeast that are discharged in the discharged liquid heavy phase.

[0054] The method may thus be used in different stages of the brewing process.

Brief description of the Drawings

[0055] The above, as well as additional objects, features and advantages of the present inventive concept, will be better understood through the following illustrative and non-limiting detailed description, with reference to the appended drawings. In the drawings like reference numerals will be used for like elements unless stated otherwise.

Figure 1 shows a schematic drawing of a centrifugal separator.

Figure 2 shows a schematic drawing of an example of a centrifuge bowl which forms part of a centrifugal separator.

Figure 3 shows portion A1 of Figure 2 in more detail.

Figure 4 shows a perspective view of a top disc.

Figure 5 shows portion A2 of Figure 2 in more detail.

Figure 6 shows a perspective view of an annular seal member.

Figure 7 illustrates a method of separating at least a liquid heavy phase from a liquid feed mixture.

Detailed Description

[0056] The centrifugal separator and the method according to the present disclosure will be further illustrated by the following description with reference to the accompanying drawings.

[0057] Figs.1 and 2 schematically show a centrifugal separator and the centrifuge bowl of the centrifugal separator of the present disclosure.

[0058] Fig. 1 show a cross-section of an embodiment of a centrifugal separator 1 configured to separate a heavy phase and a light phase from a liquid feed mixture. The centrifugal separator 1 has a rotatable part 4, comprising the centrifuge bowl 5 and drive spindle 4a.

[0059] The centrifugal separator 1 is further provided with a drive motor 3. This motor 3 may for example comprise a stationary element and a rotatable element, which rotatable element surrounds and is connected to the spin-

dle 4a such that it transmits driving torque to the spindle 4a and hence to the centrifuge bowl 5 during operation. The drive motor 3 may be an electric motor. Alternatively, the drive motor 3 may be connected to the spindle 4a by transmission means such as a drive belt or the like, and the drive motor may alternatively be connected directly to the spindle 4a.

[0060] The centrifuge bowl 5, shown in more detail in Fig. 2, is supported by the spindle 4a, which is rotatably arranged in a frame 2 around the vertical axis of rotation (X) in a bottom bearing 22 and a top bearing 21. The stationary frame 2 surrounds centrifuge bowl 5.

[0061] In the centrifugal separator as shown in Fig. 1, liquid feed mixture to be separated is fed to the bottom to the centrifuge bowl 5 via the drive spindle 4a. The drive spindle 4a is thus in this embodiment a hollow spindle, through which the feed is supplied to the centrifuge bowl 5. However, in other embodiments, the liquid feed mixture to be separated is supplied from the top, such as through a stationary inlet pipe extending into the centrifuge bowl 5.

[0062] After separation has taken place within the centrifuge bowl 5, separated liquid heavy phase is discharged through stationary outlet pipe 6a, whereas separated liquid light phase is discharged through stationary outlet pipe 7a.

[0063] Fig. 2. shows a more detailed view of the centrifuge bowl 5 of the centrifugal separator 1.

[0064] The centrifuge bowl 5 forms within itself a separation space 9a and a sludge space 9b, located radially outside the separation space 9a. In the separation space 9a, a stack 10 of separation discs 40 is arranged coaxially around the axis of rotation (X) and axially below a top disc 50. The stack 10 is arranged to rotate together with the centrifuge bowl 5 and provides for an efficient separation of the liquid feed mixture into at least a liquid light phase and a liquid heavy phase. Thus, in the separation space 9a, the centrifugal separation of the liquid feed mixture takes place during operation. The sludge space 9b is in this embodiment confined between an inner surface 13 of the centrifuge bowl 5 and an axially movable operating slide 16.

[0065] The disc stack 10 is supported at its axially lowermost portion by distributor 11. The distributor 11 comprises an annular conical base portion arranged to conduct liquid mixture from the center inlet 14 of the centrifuge bowl 5 to a predetermined radial level in the separation space 9a, and a central neck portion extending upwards from the base portion.

[0066] The centrifuge bowl 5 further comprises an inlet 14 in the form of a central inlet chamber formed within or under the distributor 11. The inlet 14 is arranged for receiving the liquid feed mixture and is thus in fluid communication with the hollow interior 4b of the spindle 4a, through which the liquid feed is supplied to the centrifuge bowl 5.

[0067] The inlet 14 communicates with the separation space 9a via passages 17 formed in the base portion of

the distributor 11. The passages 17 may be arranged so that liquid mixture is transported to a radial level that corresponds to the radial level of the cut-outs 41 provided in the separation discs 40. The cut-outs 41 form axial channels within the disc stack and distributes the liquid feed mixture throughout the disc stack 10.

[0068] There is a plurality of outlet pipes 30 for transporting separated liquid heavy phase from the sludge space 9b to a first outlet chamber 6. In Fig. 2 the outlet conduits 30 are executed as pipes having their inlet end portions 31 stretching out in the sludge space 9b to a diameter larger than the disc stack diameter. When clarifying beer, the heavy phase flowing in the outlet conduits 30 is yeast concentrate. The plurality of outlet conduits 30 have their inlet end portions 31 extending into the sludge space 9b a distance from the surrounding inner wall of the centrifuge bowl 5, i.e. so that there is a gap between the inlet end portions 31 and the surrounding wall.

[0069] The outlet conduits 30 extend from a radially outer position of the sludge space 9b to the first outlet chamber 6. The outlet conduits 30 consequently have their inlet end portions 31 arranged at the radially outer position and a conduit outlet 32 arranged at a radially inner position. The outlet conduit are arranged axially over the top disc 50, in this example so that they are both in contact with the top disc 50 and an inner wall - in this case the inner wall of the upper bowl hood 13a - of the surrounding centrifuge bowl 5. In this way, the plurality of outlet pipes 30 form an element for transmitting the axial compression force to the compressed stack 10 of separation discs.

[0070] Further, the plurality of outlet pipes 30 are arranged with an upward tilt relative the radial plane from the inlet end portions 31 to the conduit outlet 32. Further, there may be vortex nozzles arranged at the outlet end portions 32 for providing a stable flow, as discussed in WO2021058287A1.

[0071] In embodiments, the centrifugal separator comprises at least four outlet pipes 30, such as at least eight outlet pipes 30, such as at least twelve outlet pipes 30.

[0072] The radially inner portion of the disc stack 10 communicates with a second outlet chamber 7 for a separated light phase of the liquid feed mixture. The second outlet chamber 7 of the centrifuge bowl 5 communicates with a stationary outlet pipe 7a for discharging the separated liquid light phase from the centrifuge bowl 5.

[0073] The first and second outlet chambers 6, 7 have mechanical seals 12, 11. As this is an airtight design, they are also often called hermetic seals. The inlet channel 4b is also sealed at lower end of the hollow spindle 4a, thus preventing communication between the inlet channel 4b and the surroundings. This mechanical seal is not shown in this figure.

[0074] The centrifuge bowl 5 is further provided with outlets 15 at the radially outer periphery of the sludge space 9b. These outlets 15 are evenly distributed around the rotor axis (X) and are arranged for intermittent dis-

charge of a sludge component of the liquid feed mixture. The sludge component comprises denser particles forming a sludge phase. The opening of the outlets 15 is controlled by means of an operating slide 16 actuated by operating water channels below the operating slide 16, as known in the art. In its position shown in the drawing, the operating slide 16 abuts sealingly at its periphery against the upper part of the centrifuge bowl 5, thereby closing the sludge space 9b from connection with outlets 15, which are extending through the centrifuge bowl 5.

[0075] During operation of the separator as shown in Fig. 1 and 2, the centrifuge bowl 5 is brought into rotation by the drive motor 3. Via the spindle 4a, liquid feed mixture to be separated is brought into the separation space 9a, as indicated by arrow "A". Depending on the density, different phases in the liquid feed mixture is separated between the separation discs 40 of the stack 10. Heavier component, such as a liquid heavy phase and a sludge phase, move radially outwards between the separation discs of the stack 10 to the sludge space 9b, whereas the phase of lowest density, such as a liquid light phase, moves radially inwards between the separation discs of the stack 10 and is forced through the outlet pipe 7a via the second outlet chamber 7, as indicated by arrow "C". The liquid of higher density is instead discharged via the outlet conduits 30 to the first outlet chamber 6 and further out via stationary outlet pipe 6a, as indicated by arrow "B". Thus, during separation, an interphase between the liquid of lower density and the liquid of higher density is formed in the centrifuge bowl 5, such as radially within the stack of separation discs. Solids, or sludge, accumulate at the periphery of the sludge space 9b and is emptied intermittently from within the centrifuge bowl by the sludge outlets 15 being opened, whereupon sludge and a certain amount of fluid is discharged from the separation chamber 15 by means of centrifugal force, as indicated by arrow "D". However, the discharge of sludge may also take place continuously, in which case the sludge outlets 17 take the form of open nozzles and a certain flow of sludge and/or heavy phase is discharged continuously by means of centrifugal force.

[0076] Fig. 3 shows a close-up view of the portion A1 as indicated in Fig. 2. Upon assembly of the centrifuge bowl, the stack 10 of separation discs are compressed with an axial compression force, indicated by arrow "F1" in Fig. 3. This compression force F1 is exerted e.g. when assembling the bowl hood 13a and squeezes the discs of the stack 10 tightly together. According to the invention, the plurality of outlet pipes 30 form an element for transmitting this axial force F1 to the disc stack. This is achieved by having the stack 10 of separation discs being arranged just below the top disc 5 and the plurality of outlet pipes arranged tightly between the top disc 5 and the upper bowl hood 13 of the centrifuge bowl 5, i.e. so that the pipes 30 are in contact with both the top disc 50 and the inner wall of the upper bowl hood 13a.

[0077] Fig. 4 further shows a perspective view of the top disc 50 with the plurality of outlet pipes 30 arranged

on the upper surface 50a of the top disc. As seen in Fig. 4, the top disc 50 is free of any further load bearing elements on its upper surface 50a for transmitting the axial compression force F1. Thus, the top disc 50 has a more or less smooth upper surface onto which the pipes 30 are arranged. In a traditional top disc 50, there are axial wings extending axially from the upper surface. Such wings are used as load bearing elements when compressing the stack 10 of separation discs. However, according to the present invention, the outlet pipes 30 are used as such load bearing elements. Moreover, there are guiding members 55 in the form of axially extending pegs 55 on the upper surface 50a of the top disc 50. Each pipe 30 extend between two pegs 55. These pegs 55 extend axially to a lower height than the pipes 30 and have no load bearing function. Instead, they aid in further keeping the pipes firmly in position during operation of the centrifugal separator, i.e. decreasing the risk of the pipes 30 sliding in a circumferential direction on the upper surface 50a of the top disc 50.

[0078] As also seen in Fig. 4, the top disc 50 has an inner periphery 71 and an outer periphery 72. The inner periphery 71, which is thus at the smallest radius, extends radially inwards. Traditionally, the inner periphery 71 of the top disc 50 has an axially extending brim portion, i.e. an annular portion extending axially upwards from the inner periphery 71. However, in this example, the top disc 50 is free of such brim portion at its inner periphery 71. This gives more space for the plurality of outlet pipes 30 above the top disc 50, and thus facilitates mounting of the pipes 30 and transport within the pipes 30 to the outlet chamber 6.

[0079] Fig. 5 shows a close-up view of the portion A2 as indicated in Fig. 2 and thus a more detailed view of how the position of the plurality of outlet pipes 30 are secured at the upper portion of the centrifuge bowl 5. There is an annular seal member 42 in the form of a ring member extending around the axis of rotation (X). A perspective view of the annular seal member 42 is seen in Fig. 6.

[0080] The annular seal member 42 comprises through holes 43, one for each of the plurality of outlet pipes 30. Thus, the plurality of outlet pipes 30 extend through the annular seal member 42 and the annular seal member 42 thus seals around the outer periphery of the pipes 30. As discussed above, the stack 10 of separation discs is arranged below the top disc 50. The annular seal member 42 is in turn arranged axially above the top disc 50. As seen in Figs. 5 and 6, the annular seal member 42 in the form of a ring member comprises a sealing lip 42a on the inner periphery to ensure a good sealing function. This annular sealing lip 42a rests against the inner portion 71 of the top disc, i.e. the portion that extends in the radial direction.

[0081] The seal member 42 has two sealing functions. First, it seals the space 51, in which separated liquid light phase is present, from the space 52 that is between the plurality of outlet pipes (see also Fig. 4). During operation,

liquid heavy phase that is not being transported within the plurality of outlet pipes may be present in the space 52 between the pipes, i.e. liquid heavy phase may be pressed over the outer periphery 72 of the top disc 50 to the space 52 between the plurality of pipes 30. The annular seal ring 42 thus effectively seals the separated liquid light phase from being contaminated from liquid heavy phase. The space 51 is thus radially inside the stack of separation discs and in fluid connection with the second outlet chamber 7 for the separated liquid light phase. Moreover, the annular seal member further functions as a seal between the first outlet chamber 6 and the space 52 between the plurality of outlet pipes 30. Thus, the seal member 42 also effectively ensures that only separated liquid heavy phase that is transported via the plurality of outlet pipes 30 reaches the first outlet chamber 6, i.e. the separated liquid heavy phase that is present in the sludge space 9b at the radial position of the inlet portions 31 of the pipes 30.

[0082] To further secure the position of the plurality of outlet pipes 30, there is ringformed annular guide member 60 arranged for positioning the upper portions 30a of the plurality of outlet pipes 30. Also this guide member 60 is arranged around the axis of rotation (X) and comprises channels 61 through which the outlet pipes 30 extend. The annular seal member 42 is arranged below the channels 61 of the guide member 60. Moreover, the upper portion 13b of the centrifuge bowl is attached to the guide member 60 via a plurality of screws 45. This further secures the position of the upper portions 30a of the plurality of pipes 30. As indicated in Fig. 6, the annular guide member is also in close contact with both the inner wall of the bowl hood 13a and the upper portion 13b of the centrifuge bowl.

[0083] Fig. 7 illustrates a method 100 of least a liquid heavy phase from a liquid feed mixture. The method 100 comprises the steps of

a) introducing 101 the liquid feed mixture into a centrifugal separator 1. This separator may thus be a centrifugal separator as disclosed herein above, such as the centrifugal separator discussed in relation to Figs. 1-2.

[0084] The method 100 further comprises a step b) of discharging 102 a separated liquid heavy phase from the centrifugal separator. The liquid heavy phase may be discharged continuously.

[0085] The method may further comprise a step c) of discharging 103 a separated sludge phase from the centrifugal separator and a step d) of discharging 104 a separated liquid light phase from the centrifugal separator 1. The liquid light phase has thus a density that is lower than the density of the liquid heavy phase

[0086] Step c) of discharging 103 a separated sludge phase may comprise intermittently ejecting the separated solids phase through a set of intermittently openable outlets.

[0087] The liquid feed mixture may for example be a liquid feed mixture comprising yeast. The yeast may thus be discharged as the separated liquid heavy phase.

[0088] The invention is not limited to the embodiment disclosed but may be varied and modified within the scope of the claims set out below. The invention is not limited to the orientation of the axis of rotation (X) disclosed in the figures. The term "centrifugal separator" also comprises centrifugal separators with a substantially horizontally oriented axis of rotation. In the above the inventive concept has mainly been described with reference to a limited number of examples. However, as is readily appreciated by a person skilled in the art, other examples than the ones disclosed above are equally possible within the scope of the inventive concept, as defined by the appended claims.

Claims

1. A centrifugal separator (1) for separating at least a liquid heavy phase from a liquid feed mixture, comprising

a frame (2), a drive member (3) and a rotatable part (4),

wherein the drive member (3) is configured to rotate the rotatable part (4) in relation to the frame (2) around an axis of rotation (X), and wherein the rotatable part (4) comprises a centrifuge bowl (5) enclosing a separation space (9a) and a sludge space (9b);

wherein the separation space (9a) comprises a stack (10) of separation discs (40) arranged coaxially around the axis of rotation (X) and wherein said sludge space (9b) is arranged radially outside said stack (10) of separation discs (40); wherein the centrifuge bowl (5) further comprises an inlet (14) for receiving the liquid feed mixture and

a first outlet chamber (6) in fluid connection with a heavy phase outlet pipe (6a) for discharging a separated liquid heavy phase,

and wherein the centrifugal separator (1) further comprises a plurality of outlet pipes (30) for transport of said separated liquid heavy phase from said sludge space (9b) towards said first outlet chamber (6); and wherein

the stack (10) of separation discs is compressed with a compression force when mounted in the centrifuge bowl (5) and wherein said plurality of outlet pipes (30) form an element for transmitting said compression force to the compressed stack (10) of separation discs.

2. A centrifugal separator (1) according to claim 1, wherein the stack (10) of separation discs is arranged below a top disc (5), and wherein the plurality

- of outlet pipes (30) are arranged between the top disc (5) and the upper bowl hood (13a) of the centrifuge bowl (5).
3. A centrifugal separator (1) according to claim 2, wherein the top disc (5) is free of further load bearing elements on its upper surface (5a). 5
 4. A centrifugal separator (1) according to claim 1, wherein the plurality of outlet pipes (30) are arranged within the stack (10) of separation discs. 10
 5. A centrifugal separator (1) according to any previous claim, wherein the centrifugal separator (1) is arranged for separating a liquid heavy phase and a liquid light phase from the liquid feed mixture, and wherein the centrifugal separator (1) further comprises a light phase outlet pipe (7a) for discharging a separated liquid light phase. 15
 6. A centrifugal separator (1) according to any previous claim, further comprising an annular seal member (42) extending around the axis of rotation (X) and wherein the plurality of outlet pipes (30) extend through said annular seal member (42). 20
 7. A centrifugal separator (1) according to claim 5 and 6, wherein the annular seal member (42) seals a space (51) for the separated liquid light phase. 25
 8. A centrifugal separator (1) according to claim 7, wherein the annular seal member (42) seals between a space (51) for the separated liquid light phase and a space (52) between said plurality of outlet pipes (30). 30
 9. A centrifugal separator (1) according to any one of claims 6-8, wherein the annular seal member (42) further seals between the first outlet chamber (6) and a space (52) between said plurality of outlet pipes (30). 35
 10. A centrifugal separator (1) according to claim 8 or 9, wherein the stack (10) of separation discs is arranged below a top disc (50) and wherein the annular seal member (42) is arranged axially above said top disc (50). 40
 11. A centrifugal separator (1) according to any previous claim, further comprising an annular guide member (60) for positioning the upper portions (30a) of the plurality of outlet pipes (30), said annular guide member (60) comprising channels (61) through which the outlet pipes (30) extend, and further wherein an upper portion (13b) of the centrifuge bowl (5) is fastened to said annular guide member (60) via at least one screw member (45). 45
 12. A centrifugal separator (1) according to any previous claim, further comprising sludge outlets (15) at the periphery of the centrifuge bowl (5). 50
 13. A centrifugal separator (1) according to claim 12, wherein the sludge outlets (15) are in the form of a set of intermittently openable outlets. 55
 14. A method (100) of separating at least a liquid heavy phase from a liquid feed mixture, comprising the steps of
 - a) introducing (101) the liquid feed mixture into a centrifugal separator (1) according to any one of claims 1-13; and
 - b) discharging (102) a separated liquid heavy phase from said centrifugal separator (1).
 15. A method (100) according to claim 14, wherein the liquid feed mixture comprises yeast that are discharged in the discharged liquid heavy phase.

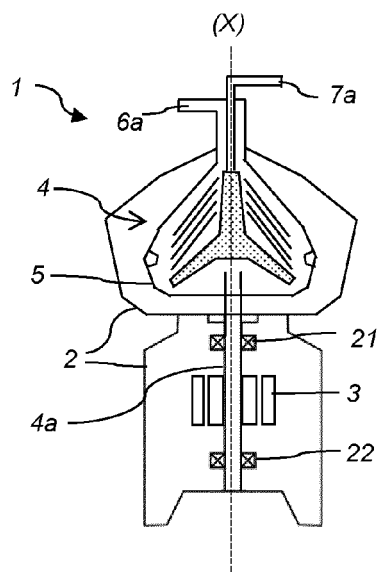


Fig. 1

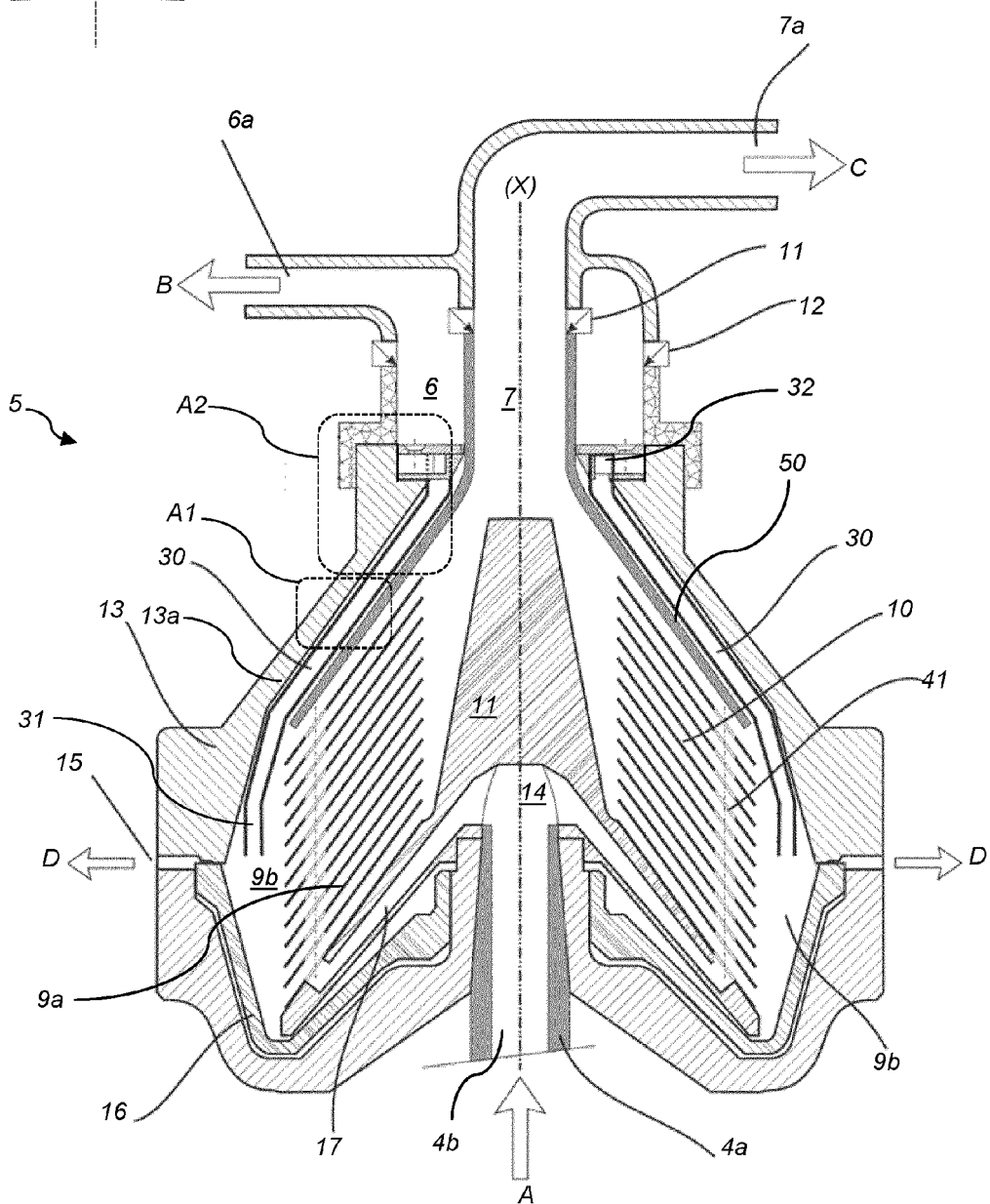


Fig. 2

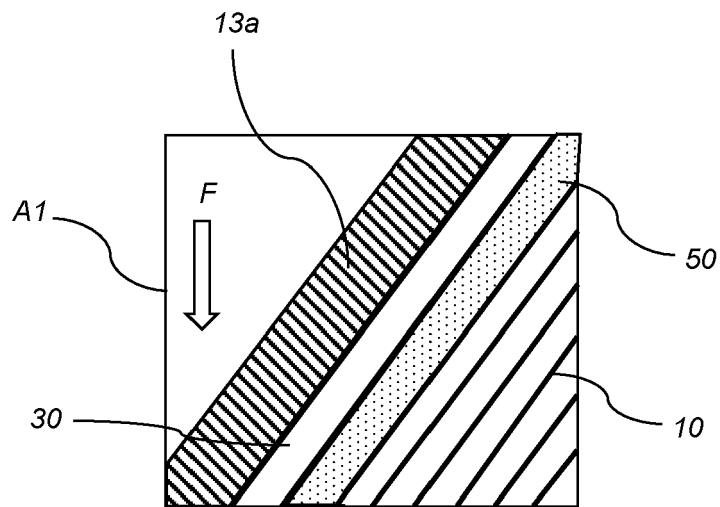


Fig. 3

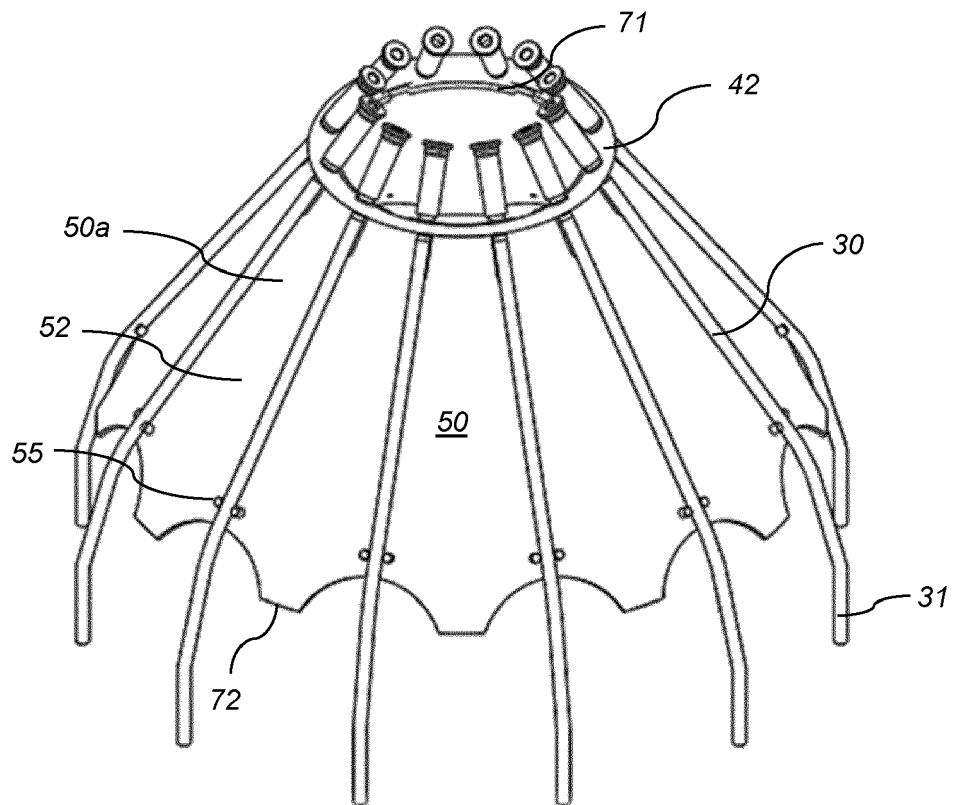


Fig. 4

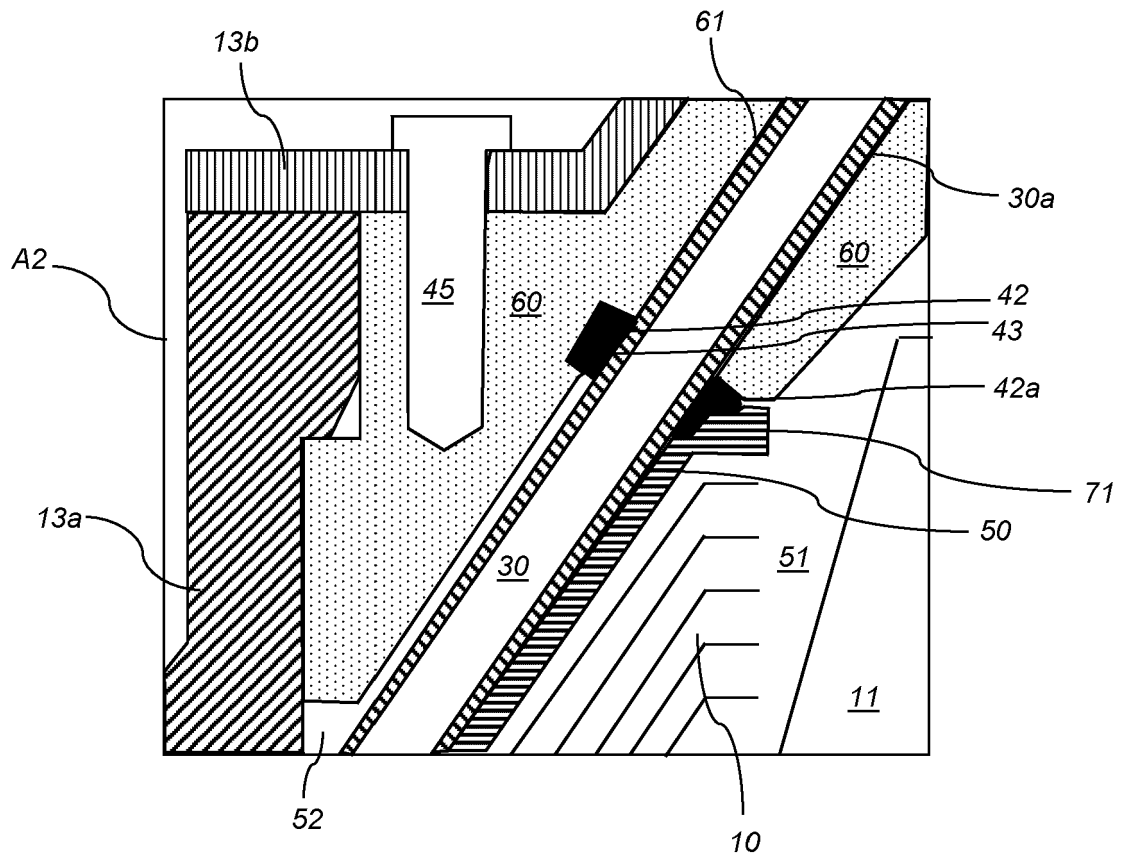


Fig. 5

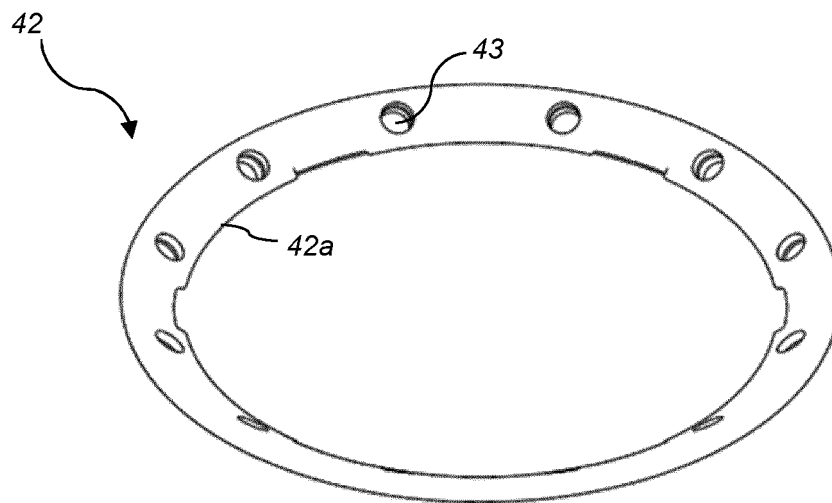


Fig. 6

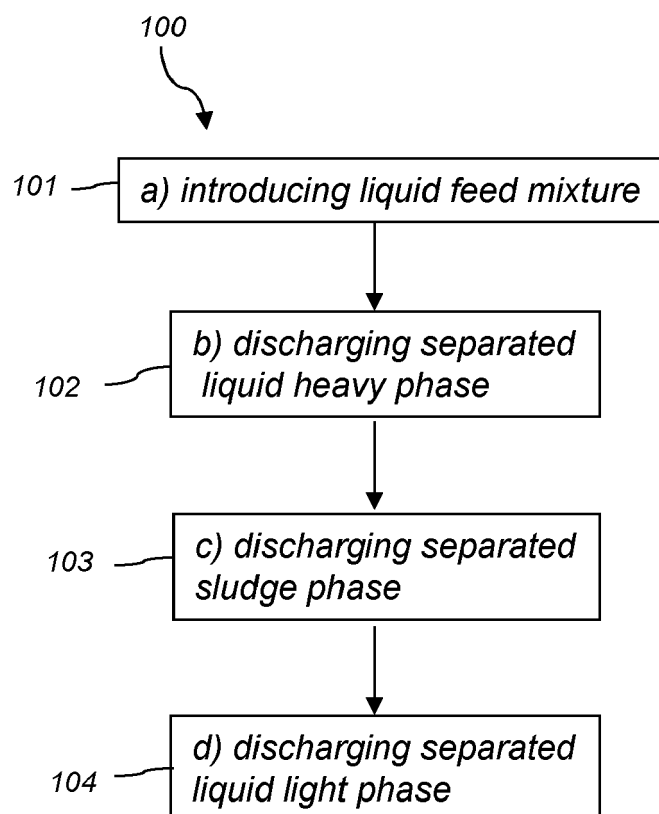


Fig. 7



EUROPEAN SEARCH REPORT

Application Number

EP 22 17 0738

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Place of search	Date of completion of the search	Examiner
Munich	13 October 2022	Leitner, Josef
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