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(54) **A CENTRIFUGAL SEPARATOR**

(57) The present invention provides a centrifugal separator (1) for separating at least one liquid phase from a liquid feed mixture. The centrifugal separator (1) is comprising a frame (2), a drive member (3) and a rotating part (4), wherein the drive member (3) is configured to rotate the rotating part (4) in relation to the frame (2) around an axis of rotation (X), and wherein the rotating part (4) comprises a centrifuge bowl (5) enclosing a separation space (9). The centrifuge bowl (5) further comprises an inlet (14) for receiving the liquid feed mixture and at least one liquid outlet (6,7) for a separated liquid phase; wherein the separation space (9) comprises surface enlarging inserts (10) for increasing the separation performance. The centrifuge bowl (5) comprises a bowl wall (30), in which a first (31) and a second (32) channel extend, wherein the first (31) and second (32) channels extend in different directions (D1, D2) but intersect at an intersection point (Y) in which there is a fluid contact between said first (31) and second (32) channels. The first channel (31) is arranged such that during rotation of the centrifuge bowl (5), stress concentration regions (40) in the bowl wall (30) are generated on two opposing sides (31a, 31b) of the first channel (31) and lower stress regions (41) are generated in the bowl wall (30) on the other two opposing sides (31c, 31d) of the first channel (31), as seen in the cross-section in the plane (A) perpendicular to the direction (D1) of the first channel (31). The second channel (32) is arranged so that it intersects the first channel (31) with its center line (Z2) shifted towards a lower stress region (31c,d), as seen in the cross-section in the plane (A) perpendicular to the direction (D1) of the first channel (31).

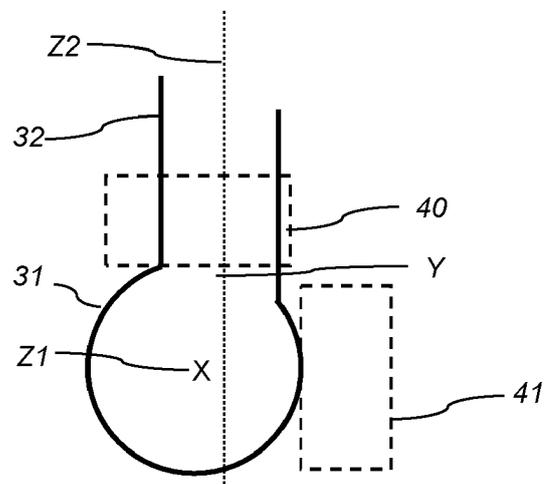


Fig. 6

EP 4 385 625 A1

Description

Field of the Invention

[0001] The present invention relates to the field of centrifugal separators, and more specifically to the formation of channels within the wall of the centrifuge bowl.

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. Separation members, such as a stack of frustoconical separation discs, are usually used within the rotating bowl in order to enhance the separation performance. An example of a centrifugal separator is described in patent application EP 3315205.

[0003] The centrifuge bowl of a centrifugal separator is subjected to a lot of stresses. As an example, when two drilled holes in a centrifuge bowl wall intersect, high stresses may occur at some points of the intersection that may eventually lead to fatigue cracks.

[0004] Thus, there is a need in the art for improved centrifugal separators in which the risk of fatigue cracks is decreased in the centrifuge bowl during operation.

Summary of the Invention

[0005] 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 a decreased risk of fatigue cracks occurring at the position where two channels intersecting each other in the centrifuge bowl wall.

[0006] As a first aspect of the invention, there is provided a centrifugal separator for separating at least one liquid phase from a liquid feed mixture, comprising

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

wherein the rotating part comprises a centrifuge bowl enclosing a separation space;

wherein the centrifuge bowl further comprises an inlet for receiving the liquid feed mixture and at least one liquid outlet for a separated liquid phase;

wherein the separation space comprises surface enlarging inserts for increasing the separation performance; and

wherein said centrifuge bowl comprises a bowl wall,

in which a first and a second channel extend, wherein the first and second channels extend in different directions (D1, D2) but intersect at an intersection point (Y) in which there is a fluid contact between said first and second channels; and wherein the first channel is arranged such that during rotation of the centrifuge bowl, stress concentration regions in the bowl wall are generated on two opposing sides of the first channel and lower stress regions are generated in the bowl wall on the other two opposing sides of the first channel, as seen in the cross-section in the plane (A) perpendicular to the direction (D1) of the first channel,

and wherein the second channel is arranged so that it intersects the first channel with its center line shifted towards a lower stress region, as seen in the cross-section in the plane perpendicular to the direction (D1) of the first channel.

[0007] 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".

[0008] The first and second channels are thus within the bowl wall of the centrifuge bowl, i.e. the wall surrounding the separation space. The first and second channels extend in different directions but intersect so that there is a fluid contact between the channels. Thus, a liquid or gas in the first channel may be guided to the second channel, and vice versa. Due to the intersection, the first and channels form a continuous channel extending in different directions.

[0009] The first and second channels may extend in any directions, i.e. there may be any angle between the first and second direction D1 and D2. The first channel may for example have a larger extension in the radial direction whereas the second channel may have a larger extension in the axial direction, or vice versa.

[0010] As seen in the in the cross-section in the plane perpendicular to the direction D1 of the first channel, the second channel may be arranged such that its direction D2 forms an angle with the direction of the force lines that are generated during rotation of the centrifuge bowl.

[0011] During rotation of the centrifuge bowl, stress concentration regions, or zones, are formed in the bowl wall adjacent to the channels. The stress concentration regions are thus regions in the bowl wall where the stress is significantly higher as compared to other regions nearby. Such stress concentration occur due to the irregularity of the material of the bowl wall due to the formed channels, which causing an interruption in the flow of stress. As seen in the in the cross-section in the plane perpendicular to the direction a channel, stress concentration

regions are formed on two opposing sides and lower stress regions are formed on the other two opposing sides. Thus, a "stress concentration region" in the bowl wall has a higher stress concentration factor than a "lower stress region" in the bowl wall.

[0012] The first aspect of the invention is based on the insight that in order to lower the stresses and minimize the risk of fatigue, the first and second channels should be formed in a way so that the channels intersect each other on the sides where at least one of the channels have their compression stresses, i.e. in a "lower stress region". Thus, the inventors have realized that the stress in the centrifuge bowl wall may be varying during operation of a centrifugal separator due to e.g. variations in liquid pressures, variations in rotational velocity and during discharge of a separated phase (such as a sludge phase). This may lead to fatigue cracks but if a channel is intersecting another channel on one of its compressive stress sides, i.e. in a "stress concentration region", the maximum stress at the intersection will be significantly lower compared to if the channel is intersecting the channel on a tensile stress side, i.e. in a "lower stress region". Therefore, the risk of cracks in the centrifuge bowl wall is decreased.

[0013] The centrifuge bowl wall may consist of or comprise a metallic material. The centrifuge bowl wall may consist of or at least comprise stainless steel.

[0014] In embodiments of the first aspect, the stress concentration regions and the lower stress regions are generated in the bowl wall due to the circumferential stress formed during rotation of the centrifuge bowl.

[0015] The circumferential stress is the force exerted circumferentially (perpendicular both to the axis of rotation and to the radius of the centrifuge bowl) in both directions on every particle in the centrifuge bowl wall.

[0016] 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 at least one liquid phase, such as one or two liquid phases, and a solids phase from a liquid feed mixture. The solids phase may be a sludge phase.

[0017] The frame of the centrifugal separator is a non-rotating part, and the rotating part may be supported by the frame by at least one bearing device, which may comprise a ball bearing. The rotating 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 rotating part comprises a centrifuge bowl. The centrifuge bowl is usually supported by a spindle, i.e. a rotating shaft, and may thus be mounted to rotate with the spindle. Consequently, the rotating 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.

[0018] The drive member for rotating the rotating part of the separator may comprise an electrical motor having

a rotor and a stator. The rotor may be fixedly connected to the rotating part, such as to a spindle. Advantageously, the rotor of the electrical motor may be provided on or fixed to the spindle of the rotating part. Alternatively, the drive member may be provided beside the spindle and rotate the rotating part by a suitable transmission, such as a belt or a gear transmission.

[0019] The centrifuge bowl encloses by rotor walls a separation space. The separation space, in which the separation of the fluid mixture takes place, comprises surface enlarging inserts for increasing the separation performance. Such inserts may be a stack of separation discs arranged coaxially around the axis of rotation (X). The separation discs are arranged at a distance from each other to form interspaces between each two adjacent 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. As an example, the stack of separation discs may comprise more than 100 separation discs, such as more than 200 separation discs. The thickness of a separation disc may be less than 1 mm, such as less than 0.6 mm.

[0020] 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, such as through a stationary inlet pipe extending into the centrifuge bowl.

[0021] The at least one liquid outlet may be arranged on an upper portion of the centrifuge bowl, such as axially above the stack of separation discs. The at least one liquid outlet may be a single outlet for a separated liquid phase or comprise a first liquid outlet for a liquid light phase and a second liquid outlet for a liquid heavy phase. The liquid heavy phase has a density that is higher than the density of the liquid light phase.

[0022] In embodiments of the first aspect, the centrifugal separator further comprises a sludge outlet arranged at the periphery of the centrifuge bowl. As an example, the sludge outlet may be in the form of a set of intermittently openable outlets or a set of permanently open nozzles.

[0023] The centrifugal separator may thus be arranged to separate the liquid feed mixture into a liquid light phase, a liquid heavy phase and a solids phase, i.e. a sludge phase, and hence, the centrifugal separator may comprise a first liquid outlet for a heavy phase, a second liquid outlet for a light phase and sludge outlets for separated sludge.

[0024] The radius of the first and/or second channel may be at least 2 mm, such as at least 5 mm, such as at least 10 mm.

[0025] In embodiments of the first aspect, the second

channel is shifted with its center line (Z2) towards a lower stress region at least a distance that is half of the radius of the first channel, as seen in the cross-section in the plane (A) perpendicular to the direction of the first channel. The center line Z2 is thus along the direction D2 of the second channel.

[0026] As an example, the second channel may be shifted with its center line (Z2) towards a lower stress region at least a distance that is radius of the first channel, as seen in the cross-section in the plane (A) perpendicular to the direction of the first channel. Thus, the center line Z2 may be shifted so that it does not overlap with the cross section of the first section.

[0027] In embodiments of the first aspect, the second channel is shifted with its center line (Z2) towards a lower stress region such that an imaginary extension of the second channel does not overlap with the center line (Z1) of the first channel.

[0028] The imaginary extension is thus an extension along the direction D2 of the second channel. The second channel may be arranged such that an imaginary extension does not overlap the center line of the first channel, i.e. the center line of the first channel is outside the imaginary extension of the second channel.

[0029] In embodiments of the first aspect, the centrifuge bowl has a radius R and said intersection point (Y) is arranged at a radius that is more than 0.3R, such as more than 0.5R.

[0030] The risk of fatigue cracks may be higher at larger radius of the centrifuge bowl, i.e. it may be more useful to use the teachings of the present invention for a first and second channel that are located on a large radius

[0031] The radius R of the centrifuge bowl may be at least 120 mm, such as at least 150 mm, such as at least 200 mm.

[0032] In embodiments of the first aspect, the second channel is arranged so that the intersection point (Y) between the first and second channel is also shifted towards a lower stress region of said second channel.

[0033] The first and second channels may be arranged so that the channels intersect each other on the sides where both of the channels have their compression stresses, i.e. in a "lower stress region" of both channels.

[0034] Consequently, also the second channel may be arranged such that during rotation of the centrifuge bowl, stress concentration regions in the bowl wall are generated on two opposing sides of the second channel and lower stress regions are generated in the bowl wall on the other two opposing sides of the second channel, as seen in the cross-section in the plane perpendicular to the direction (D2) of the second channel. The second channel may then be arranged so that it intersects the first channel with its center line shifted towards a lower stress region of the first channel, as seen in the cross-section in the plane perpendicular to the direction (D1) of the first channel, and also so that the center line of the first channel is shifted towards a lower stress region of the second channel, as seen in the cross-section in the

plane perpendicular to the direction (D2) of the second channel.

[0035] In embodiments of the first aspect, the first channel and second channel are connected to a liquid outlet for a separated liquid phase.

[0036] Thus, the first and second channels may form part of an outlet channel through which a separated phase, such as a liquid heavy phase, is transported after separation in the separation space.

[0037] In embodiments of the first aspect, the centrifugal separator further comprises a sludge outlet arranged at the periphery of the centrifuge bowl. The first channel and second channel may then be part of the liquid system used for intermittently discharging sludge from such sludge outlet.

[0038] In certain types of centrifugal separators, separated sludge is discharged through a number of ports in the periphery of the separator bowl. Between discharges these ports are covered by e.g. an operating slide, which forms an internal bottom in the separating space of the bowl. Such an operating slide may be pressed up against the upper part of the bowl to cover the ports by the force of a hydraulic fluid, such as water, underneath. In order to initiate a sludge discharge, the hydraulic fluid is drained from underneath the operating slide so that the lifting force acting to press the operating slide upwards is decreased, which in turn initiates a motion of the operating slide so that the ports are opened. To close the ports again, hydraulic fluid is yet again supplied to the space underneath the operating slide. Such hydraulically operated systems allows for opening and closing of the ports for only a fraction of a second and may result in partial or complete emptying of the content in the separation bowl.

[0039] The first and second channels may be part of a system for transporting hydraulic fluid to move the operating slide up or down. As an example, the first and second channels may be connected to an operating water module (OWM) arranged for supplying water to the intermittent discharge system.

[0040] The first and second channels may also be part of a different type of intermittent discharge system, such as a system using at least one actuator for closing and opening the sludge outlets. Thus, the first and second channels may be channels comprising an electrical wire.

[0041] In embodiments of the first aspect, the centrifuge bowl comprises at least one sensor for measuring a physical property of the centrifuge bowl itself or a physical property within the centrifuge bowl, and wherein said first channel and second channel comprises a wire connected to said at least one sensor.

[0042] The wire may for example be an electrical wire or an optical wire. The at least one sensor may be arranged within the separation space or in the bowl wall. As an example, the at least one sensor may be arranged on the inner surface of the bowl wall, i.e. on the surface facing the separation space.

[0043] The at least one sensor may be configured for

sensing e.g. a temperature or a pressure within the bowl.

[0044] In embodiments of the first aspect, the first channel and/or second channel has been formed by a method selected from drilling and Electrical discharge machining (EDM).

[0045] In EDM, electrical discharges (sparks) are used for creating a channel.

[0046] As a second aspect of the invention, there is provided a method of forming a first channel and a second channel in the bowl wall of a centrifuge bowl for a centrifugal separator. The method is comprising the steps of

- a) providing said centrifuge bowl;
- b) forming said first channel extending in a first direction D1 in the bowl wall wherein the first channel is formed such that during rotation of the centrifuge bowl, stress concentration regions in the bowl wall are generated on two opposing sides of the first channel and lower stress regions are generated in the bowl wall on the other two opposing sides of the first channel, as seen in the cross-section in the plane (A) perpendicular to the direction (D1) of the first channel,
- c) forming said second channel extending in a second direction in the bowl wall such that said first and second channels intersect at an intersection point (Y) in which there is a fluid contact between said first and second channels and wherein said second direction D2 is different from said first direction D1, and wherein the second channel is formed so that it intersects the first channel with its center line (Z2) shifted towards a lower stress region, as seen in the cross-section in the plane (A) perpendicular to the direction (D1) of the first channel.

[0047] 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.

[0048] Steps b) and or c) may be performed using method selected from drilling and Electrical discharge machining (EDM).

[0049] The method of the second aspect may be used for producing a centrifuge bowl for a centrifugal separator according to the first aspect discussed above.

[0050] In embodiments of the second aspect, the second channel is formed in step c) such that the second channel is shifted with its center line (Z2) towards a lower stress region at least a distance that is half of the radius of the first channel, as seen in the cross-section in the plane (A) perpendicular to the direction (D1) of the first channel.

[0051] In embodiments of the second aspect, the second channel is formed in step c) such that the second channel is shifted with its center line (Z2) towards a lower stress region such that an imaginary extension (32a) of

the second channel does not overlap with the center line (Z1) of the first channel.

[0052] In embodiments of the second aspect, the centrifuge bowl has a radius R and steps b) and c) are performed such that the intersection point (Y) is arranged at a radius that is more than 0.3R, such as more than 0.5R.

[0053] As discussed in relation to the first aspect above, the first and second channels may be formed so that the channels intersect each other on the sides where both of the channels have their compression stresses, i.e. in a "lower stress region" of both channels. Consequently, in embodiments of the second aspect, step c) is comprising forming the second channel such that during rotation of the centrifuge bowl, stress concentration regions in the bowl wall are generated on two opposing sides of the second channel and lower stress regions are generated in the bowl wall on the other two opposing sides of the second channel, as seen in the cross-section in the plane (A) perpendicular to the direction (D2) of the second channel.

[0054] Step c) may then also comprise forming the second channel so that it intersects the first channel with its center line shifted towards a lower stress region of the first channel, as seen in the cross-section in the plane perpendicular to the direction (D1) of the first channel, and also so that the center line of the first channel is shifted towards a lower stress region of the second channel, as seen in the cross-section in the plane perpendicular to the direction (D2) of the second channel

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 according to an embodiment of the present invention.

Figure 2 shows a schematic drawing of a cross-section of a centrifuge bowl.

Figure 3 shows a schematic perspective view of a first and second channels intersecting.

Figure 4 shows a schematic drawing of the internal force lines around a first channel, as seen in a plane that is perpendicular to the direction of the first channel.

Figure 5 shows a schematic drawing of a first and second channel intersecting according to a prior art method, as seen in a plane that is perpendicular to the direction of the first channel.

Figure 6 shows a schematic drawing of a first and second channel intersecting, as seen in a plane that is perpendicular to the direction of the first channel.

Figure 7 shows a schematic drawing of a first and second channel intersecting, as seen in a plane that is perpendicular to the direction of the first channel. Figure 8 shows exemplary positions of the first and second channels within the bowl wall of the centrifuge bowl.

Figure 9 shows a flow chart of a method of forming a first and a second channel in the bowl wall of a centrifuge bowl for a centrifugal separator

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] Fig. 1 show a cross-section of an embodiment of a centrifugal separator 1 configured to separate at least one liquid phase - in this case a liquid heavy phase and a liquid light phase - from a liquid feed mixture. The centrifugal separator 1 has a rotating part 4, comprising the centrifuge bowl 5 and drive spindle 4a.

[0058] 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 spindle 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. The transmission means may be in the form of a worm gear comprising an element connected to the spindle 4a in order to receive driving torque. The transmission means may alternatively take the form of drive belts or the like.

[0059] The centrifuge bowl 5, shown in more detail in Fig. 2, is supported by the spindle 4a, which in turn is rotatably arranged in the stationary 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. The drive motor 3 is thus configured to rotate the rotating part 4 in relation to the frame around the vertical axis of rotation (X).

[0060] In the centrifugal separator as shown in Fig. 1, liquid feed to be separated is fed from 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 may be supplied from the top, such as through a stationary inlet pipe extending into the centrifuge bowl 5.

[0061] 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.

[0062] Fig. 2. shows a more detailed view of the cen-

trifuge bowl 5 of the centrifugal separator 1.

[0063] The centrifuge bowl 5 forms within itself, i.e. encloses, a separation space 9. In the separation space 9, a stack 10 of separation discs 10a is arranged coaxially around the axis of rotation (X) and axially below a top disc 11. The stack 10 is thus arranged to rotate together with the centrifuge bowl 5 and for a surface enlarging insert in the centrifuge bowl 5, thereby providing for an efficient separation of the liquid mixture into at least a liquid light phase and a liquid heavy phase. Thus, in the separation space 9, centrifugal separation of e.g. a liquid feed mixture takes place during operation.

[0064] The separation discs 10a in the stack 10 are separated by distance members. Such members are arranged on the conical portions of the separation discs and are arranged so that interspaces are formed between adjacent separation discs 10a in the disc stack 10.

[0065] The stack 10 is supported at its axially lowermost portion by distributor 13. The distributor 13 comprises a base portion 13a and a central neck portion extending upwards from the base portion 13a. The distributor 13 is arranged to conduct liquid mixture from the center inlet 14 of the centrifuge bowl 5 to a radial level in the separation space 9.

[0066] The inlet 14 is in the form of a central inlet chamber formed within or under the distributor 13. 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 9 via passages 20 formed in or under the base portion 13a of the distributor 13.

[0068] The passages 20 may be arranged so that liquid mixture is transported to a radial level that corresponds to the radial level of the cut-outs 10c provided in the separation discs 10a. The cut-outs 10c form axial channels within the disc stack and distributes the liquid feed mixture throughout the disc stack 10.

[0069] The top disc 11 and an upper inner wall of the centrifuge bowl 5 delimits at least one channel 25 extending from the radially outer portion of the separation space 9 towards a central portion of the centrifuge bowl 5. The first liquid outlet 6 is arranged in a first outlet chamber 15, which is in fluid communication with the at least one channel 25 for discharge of a separated liquid heavy phase.

[0070] The radially inner portion of the disc stack 10 communicates with a second outlet 7 for a separated liquid light phase of the liquid feed mixture. The second outlet 7 is arranged in a second outlet chamber 8.

[0071] The centrifuge bowl 5 is further provided with outlets 17 at the radially outer periphery of the separation space 9. These outlets 17 are evenly distributed around the axis of rotation (X) and are arranged for intermittent discharge of a sludge component of the liquid feed mixture. The sludge component comprises denser particles forming a sludge phase. The opening of the outlets 17 is

controlled by means of an operating slide 18 actuated by operating water in channel 19, as known in the art. In its position shown in the drawing, the operating slide 18 abuts sealingly at its periphery against the upper part of the centrifuge bowl 5, thereby closing the separation space 9 from connection with outlets 17, which are extending through the centrifuge bowl 5.

[0072] 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 9. Depending on the density, different phases in the liquid feed mixture is separated between the separation discs 10a of the stack 10. Heavier component, such as a liquid heavy phase and a sludge phase, move radially outwards between the separation discs 10a to the radially outer portion of the separation space 9, whereas the phase of lowest density, such as a liquid light phase, moves radially inwards between the separation discs 10a and is forced through second outlet 7 arranged in the second liquid outlet chamber 8. The liquid of higher density is instead forced out through the passages 25 over the top disc 11 to the liquid outlet 6 for the liquid heavy phase. 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 separation space and is emptied intermittently from within the centrifuge bowl by the sludge outlets 17 being opened, whereupon sludge and a certain amount of fluid is discharged from the separation chamber 17 by means of centrifugal force. 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.

[0073] Fig. 3 shows a first 31 and second 32 channel extending in the bowl wall 30 of the centrifuge bowl 5. In this example, the first 31 and second 32 channels have been formed by drilling, but might as well have been formed by another method, such as Electrical discharge machining (EDM). The first channel 31 extends in a first direction D1 and the second channel 32 extends in a second direction D2, which is different from the first direction D1. D1 and D2 may be any direction relative the rotational axis X of the centrifuge bowl 5. The two channels 31, 32 intersect at intersection point Y, in which there is a fluid contact between the first 31 and second 32 channels. Shown in Fig. 3 is also the plane A, which will be referred to in relation to the discussion about Figs. 4-7 below. Plane A is thus a plane that is perpendicular to the direction, or extension, D1 of the first channel 31.

[0074] Fig. 4 shows the cross section of the first channel 31 as seen in plane A discussed in relation to Fig. 3 above. Shown schematically in Fig. 4 are also the internal force lines 5 of the material of the bowl wall 30. These force lines 5 of the bowl wall 30 represent the flow of

force around the first channel 31 that are generated when the centrifuge bowl 5 is subjected to stress σ , which may thus be the circumferential stress formed during rotation of the centrifuge bowl 5. The spacing between the force lines 50 reflects the stress concentration. As known in theory, stress concentration regions 40 are formed in the material adjacent to two opposing sides 31a, 31b of the first channel 31, and lower stress regions 41 are formed in the material adjacent to the other two opposing sides 31c, 31d of the first channel 31, as seen in plan A. If calculating around a hole in an infinite plate, the stress concentration is three times higher in a stress concentration region 40 as compared to a lower stress region 41, regardless of the size of the hole or in this case the diameter of the cross section of the first channel 31. The lower stress regions 41 may thus be the regions in the bowl wall 30 adjacent to the first channel in which the stress is lowest.

[0075] Fig. 5 represent a prior art situation in which the second channel 32 is formed to intersect the first channel 31. As illustrated in Fig. 5, the second channel 32 is arranged such that it is centered on the first channel, i.e. so that the center line Z2 of the second channel is aligned with the center line Z1 of the first channel 31. The center line Z2 of the second channel 32 is thus aligned with the direction D2 of the second channel 32. Further, an imaginary extension 32a of the second channel 32 into the first channel 31 will in this prior art situation enclose the center line Z1 of the first channel 31.

[0076] The inventors have realised that such a prior art solution will give rise to a higher risk of fatigue cracks if the stress is varying, which it typically does within a centrifuge bowl, e.g. due to differences in rotational velocity. Thus, according to the present invention, the second channel 32 is arranged so that it intersects the first channel 31 with its center line Z2 shifted towards a lower stress region 31c,d, as seen in the cross-section in the plane A that is perpendicular to the direction D1 of the first channel 31. This is indicated in Fig. 6, in which the second channel 32 is shifted towards a low stress region 41, as seen in plan e A. This will decrease the risk of fatigue cracks in the centrifuge bowl wall 30. As an example, the second channel 32 may be shifted with its center line Z2 towards a lower stress region 41 at least a distance that is half of the radius of the first channel 31, as seen in the cross-section in the plane A that is perpendicular to the direction D1 of the first channel 31.

[0077] The embodiment in Fig. 7 illustrates an example in which the second channel 2 is shifted with its center line Z2 towards a lower stress region 41 such that an imaginary extension 32a of the second channel 32 does not overlap with the center line Z1 of the first channel 31, as seen in the cross-section in the plane A that is perpendicular to the direction D1 of the first channel 31.

[0078] During rotation of the centrifuge bowl 5, stress concentration regions in the bowl wall 30 may also be generated on two opposing sides of the second channel 32 and lower stress regions may be generated in the

bowl wall on the other two opposing sides of the second channel 32, as seen in a cross-section in the plane perpendicular to the direction (D2) of the second channel 32. The intersection point Y may then be shifted so that it is both in a lower stress region of the first channel 31 and in a lower stress region of the second channel 32.

[0079] The first 31 and second 32 channels may be arranged within the centrifuge bowl 5 such that the intersection point Y is at a larger large radius, i.e. at a position at which the centrifugal forces are large. As an example, and as illustrated in Fig. 8, the centrifuge bowl 5 may have a radius of R, and the intersection point Y may be arranged at a radius that is more than 0.3R, such as more than 0.5R.

[0080] As discussed above, the first 31 and second 32 channels may be arranged anywhere and for any purpose in the centrifuge bowl. This is schematically shown in Fig. 8, which shows the centrifuge bowl 5 and its bowl wall 30. The first 31 and second 32 channels may for example be arranged so that they are connected to a liquid outlet 6 for a separated liquid phase, such as a separated liquid heavy phase. Thus, the separated phase may flow within the first 31 and second 32 channels on its way to the liquid outlet 5.

[0081] Also, the first channel 31 and the second channel 32 form part of the liquid system 50 used for intermittently discharging sludge from a sludge outlet. Thus, the first 31 and second 32 channels may be arranged for transporting operating water to or from an operating water module (OWM), which is arranged outside the centrifuge bowl 5. As an example, the first 31 and second 32 channels may be arranged for transporting the water needed for pressing the operating slide 18 in its upwards position, thereby closing the sludge outlets 17 (see Fig. 1).

[0082] The first 31 and second 32 channels may also be used as for providing wires to different sensors or actuators within the centrifuge bowl. As an example, and as illustrated in Fig. 8, the centrifuge bowl 5 may comprises a sensor 51 for measuring a physical property of the centrifuge bowl 5 itself or a physical property within the centrifuge bowl 5. Such sensor may for example be a temperature or pressure sensor used for measuring the temperature and/or pressure of the liquid mixture that is separated in the separation space. Thus, the sensor 51 may be arranged for measuring a physical property of the liquid mixture in the separation space. The first 31 and second 32 channels may then comprise at least on wire for electrical or optical connection from the outside of the bowl wall 30 to such sensor 51.

[0083] Fig. 9 illustrates the basic steps of a method 100 for forming a first channel 31 and a second channel 32 in the bowl wall 30 of a centrifuge bowl 5 for a centrifugal separator 1. The method may thus be used for forming the channels in a centrifuge bowl as discussed in relation to Figs. 1-8 above. The method 100 comprises a first step a) of providing 01 the centrifuge bowl 5 and a step b) of forming 102 said first channel 31 extending

in a first direction D1 in the bowl wall 30, wherein the first channel 31 is formed such that during rotation of the centrifuge bowl, stress concentration regions 40 in the bowl wall 30 are generated on two opposing sides 31a, 31b of the first channel 31 and lower stress regions 41 are generated in the bowl wall 3) on the other two opposing sides 31c, 31d of the first channel 31, as seen in the cross-section in the plane A perpendicular to the direction D1 of the first channel (31).

[0084] The method 100 is also comprising a step c) of forming 103 said second channel 32 extending in a second direction D2 in the bowl wall 30 such that said first 31 and second 32 channels intersect at an intersection point Y in which there is a fluid contact between said first 31 and second 32 channels and wherein said second direction D2 is different from said first direction D1, and wherein the second channel 32 is formed so that it intersects the first channel 31 with its center line Z2 shifted towards a lower stress region 31c, 31d, as seen in the cross-section in the plane A perpendicular to the direction D1 of the first channel 31.

[0085] Steps b) and c) may for example be performed by drilling the first 31 and/or second 32 channels or forming the first 31 and/or second 32 channels using Electrical discharge machining (EDM).

[0086] As discussed in relation to Figs. 6 and 7 above, the second channel 32 may be formed in step c) such that the second channel 32 is shifted with its center line Z2 towards a lower stress region 41 at least a distance that is half of the radius of the first channel 31, as seen in the cross-section in the plane A perpendicular to the direction D1 of the first channel 31.

[0087] Also, as discussed in relation to Figs. 6 and 7 above, the second channel 32 may be formed in step c) such that the second channel 32 is shifted with its center line Z2 towards a lower stress region 41 such that an imaginary extension 32a of the second channel 32 does not overlap with the center line Z1 of the first channel 31.

[0088] Further, the first 31 and second 32 channels may intersect at a large radius. AS an example, centrifuge bowl 5 may have a radius R and steps b) and c) may be performed such that the intersection point Y between the first 31 and second 32 channel may be arranged at a radius that is more than 0.3R, such as more than 0.5R.

[0089] The invention is not limited to the embodiments 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 one liquid phase from a liquid feed mixture, comprising

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

wherein the drive member (3) is configured to rotate the rotating part (4) in relation to the frame (2) around an axis of rotation (X), and

wherein the rotating part (4) comprises a centrifuge bowl (5) enclosing a separation space (9); wherein the centrifuge bowl (5) further comprises an inlet (14) for receiving the liquid feed mixture and at least one liquid outlet (6,7) for a separated liquid phase;

wherein the separation space (9) comprises surface enlarging inserts (10) for increasing the separation performance; and

wherein said centrifuge bowl (5) comprises a bowl wall (30), in which a first (31) and a second (32) channel extend,

wherein the first (31) and second (32) channels extend in different directions (D1, D2) but intersect at an intersection point (Y) in which there is a fluid contact between said first (31) and second (32) channels; and wherein

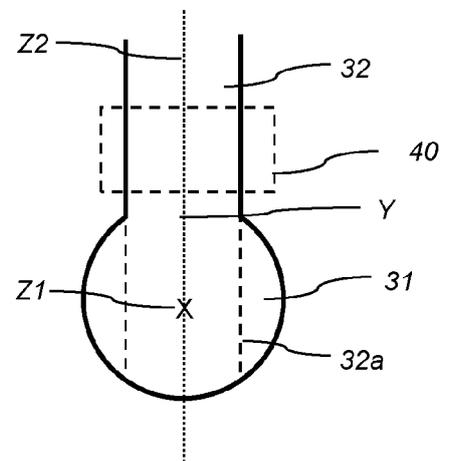
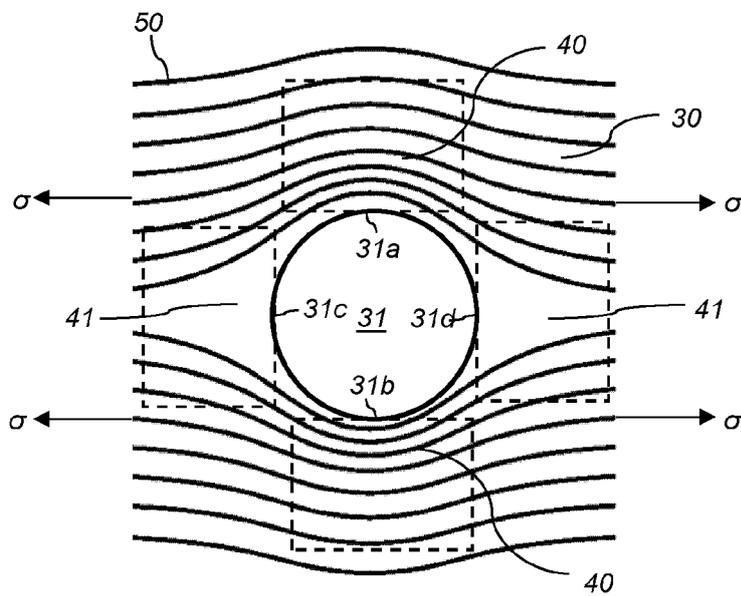
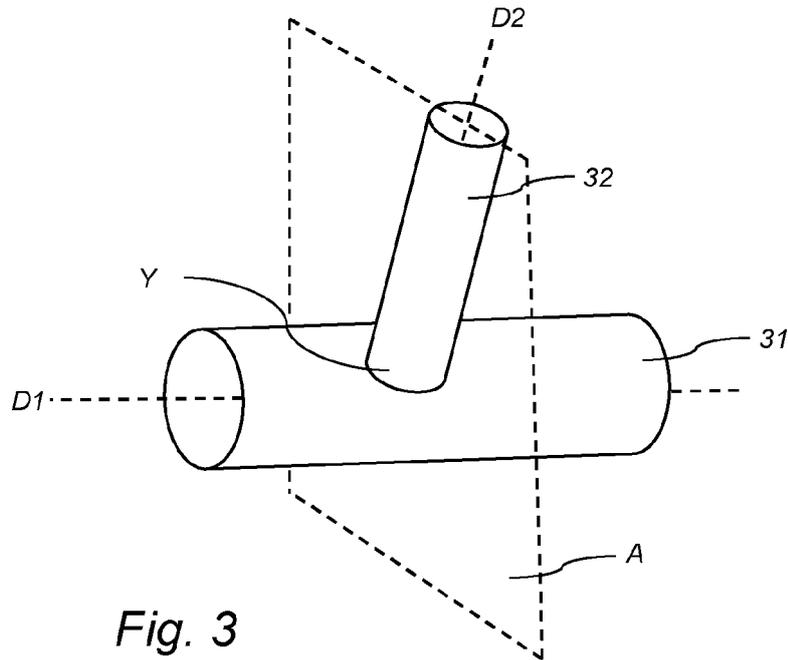
the first channel (31) is arranged such that during rotation of the centrifuge bowl (5), stress concentration regions (40) in the bowl wall (30) are generated on two opposing sides (31a, 31b) of the first channel (31) and lower stress regions (41) are generated in the bowl wall (30) on the other two opposing sides (31c, 31d) of the first channel (31), as seen in the cross-section in the plane (A) perpendicular to the direction (D1) of the first channel (31),

and wherein the second channel (32) is arranged so that it intersects the first channel (31) with its center line (Z2) shifted towards a lower stress region (31c,d), as seen in the cross-section in the plane (A) perpendicular to the direction (D1) of the first channel (31).
2. A centrifugal separator (1) according to claim 1, wherein said stress concentration regions (40) and said lower stress regions (41) are generated in the bowl wall due to the circumferential stress formed during rotation of the centrifuge bowl (5).
3. A centrifugal separator (1) according to claim 1 or 2, wherein the second channel (32) is shifted with its center line (Z2) towards a lower stress region (41) at least a distance that is half of the radius of the first channel (31), as seen in the cross-section in the plane (A) perpendicular to the direction (D1) of the first channel (31).
4. A centrifugal separator (1) according to any previous claim, wherein the second channel (32) is shifted with its center line (Z2) towards a lower stress region (41) such that an imaginary extension (32a) of the second channel (32) does not overlap with the center line (Z1) of the first channel (31).
5. A centrifugal separator (1) according to any previous claim, wherein said centrifuge bowl (5) has a radius R and said intersection point (Y) is arranged at a radius that is more than 0.3R, such as more than 0.5R.
6. A centrifugal separator (1) according to any previous claim, wherein said second channel (32) is arranged so that the intersection point (Y) between the first (31) and second (32) channel is also shifted towards a lower stress region of said second channel (32)
7. A centrifugal separator (1) according to any previous claim, wherein said first channel (31) and second channel (32) are connected to a liquid outlet (6,7) for a separated liquid phase.
8. A centrifugal separator (1) according to any previous claim, wherein the centrifugal separator further comprises a sludge outlet (17) arranged at the periphery of the centrifuge bowl (5).
9. A centrifugal separator (1) according to claim 8, wherein said first channel (31) and second channel (32) are part of the liquid system used for intermittently discharging sludge from said sludge outlet.
10. A centrifugal separator (1) according to any previous claim, wherein said centrifuge bowl (5) comprises at least one sensor (51) for measuring a physical property of the centrifuge bowl (5) itself or a physical property within the centrifuge bowl (5), and wherein said first channel (31) and second channel (32) comprises a wire connected to said at least one sensor
11. A centrifugal separator (1) according to any previous claim, wherein said first channel (31) and/or second channel (32) has been formed by a method selected from drilling and Electrical discharge machining (EDM).
12. A method (100) of forming a first channel (31) and a second channel (32) in the bowl wall (30) of a centrifuge bowl (5) for a centrifugal separator (1), comprising the steps of
 - a) providing (101) said centrifuge bowl (5);
 - b) forming (102) said first channel (31) extending in a first direction D1 in the bowl wall (30), wherein the first channel (31) is formed such that during rotation of the centrifuge bowl (5), stress con-

centration regions (40) in the bowl wall (30) are generated on two opposing sides (31a, 31b) of the first channel (31) and lower stress regions (41) are generated in the bowl wall (30) on the other two opposing sides (31c, 31d) of the first channel (31), as seen in the cross-section in the plane (A) perpendicular to the direction (D1) of the first channel (31),

c) forming (103) said second channel (32) extending in a second direction D2 in the bowl wall (30) such that said first (31) and second (32) channels intersect at an intersection point (Y) in which there is a fluid contact between said first (31) and second (32) channels and wherein said second direction D2 is different from said first direction D1, and wherein the second channel (32) is formed so that it intersects the first channel (31) with its center line (Z2) shifted towards a lower stress region (31c,d), as seen in the cross-section in the plane (A) perpendicular to the direction (D1) of the first channel (31).

13. A method (100) according to claim 12, wherein the second channel (32) is formed in step c) such that the second channel (32) is shifted with its center line (Z2) towards a lower stress region (41) at least a distance that is half of the radius of the first channel (31), as seen in the cross-section in the plane (A) perpendicular to the direction (D1) of the first channel (31).
14. A method (100) according to claim 12 or 13, wherein the second channel (32) is formed in step c) such that the second channel (32) is shifted with its center line (Z2) towards a lower stress region (41) such that an imaginary extension (32a) of the second channel (32) does not overlap with the center line (Z1) of the first channel (31).
15. A method (100) according to any one of claims 12-14, wherein said centrifuge bowl (5) has a radius R and wherein steps b) and c) are performed such that said intersection point (Y) is arranged at a radius that is more than 0.3R, such as more than 0.5R.



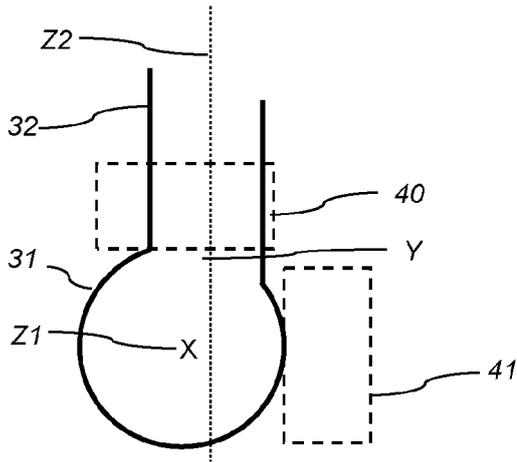


Fig. 6

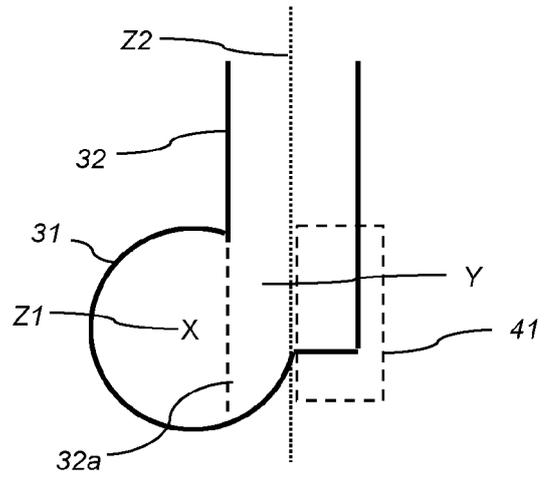


Fig. 7

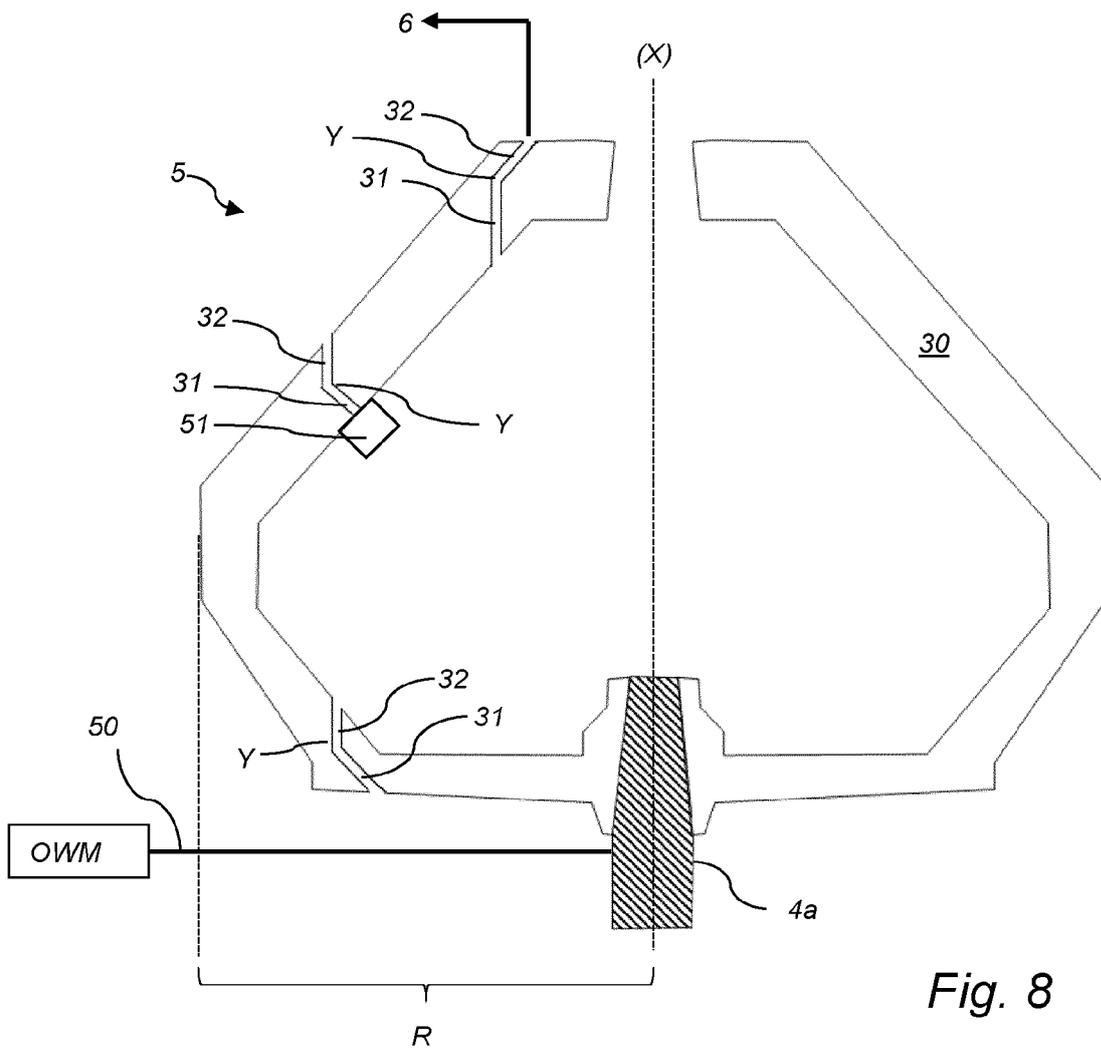


Fig. 8

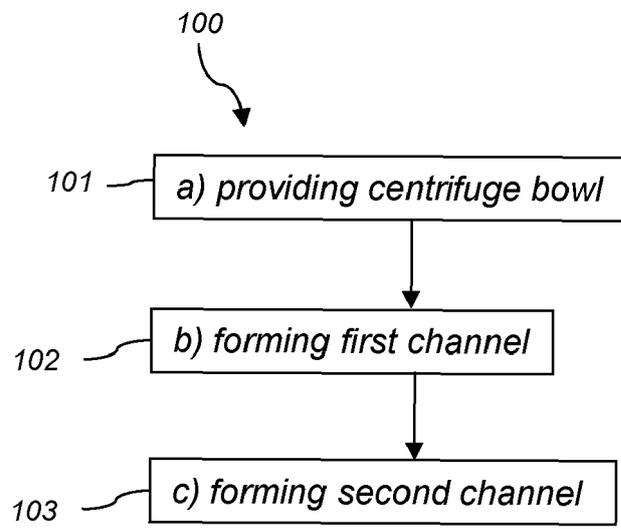


Fig. 9



EUROPEAN SEARCH REPORT

Application Number
EP 22 21 3463

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	<p>EP 3 315 205 A1 (ALFA LAVAL CORP AB [SE]) 2 May 2018 (2018-05-02) * paragraph [0163]; claims 1,12; figure 7 *</p> <p style="text-align: center;">-----</p>	1-15	<p>INV. B04B1/08 B04B7/06 B04B7/08</p>
			<p>TECHNICAL FIELDS SEARCHED (IPC)</p>
			<p>B04B</p>
<p>The present search report has been drawn up for all claims</p>			
<p>Place of search</p> <p>Munich</p>		<p>Date of completion of the search</p> <p>30 May 2023</p>	<p>Examiner</p> <p>Laurim, Jana</p>
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document</p>			

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30-05-2023

10	Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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