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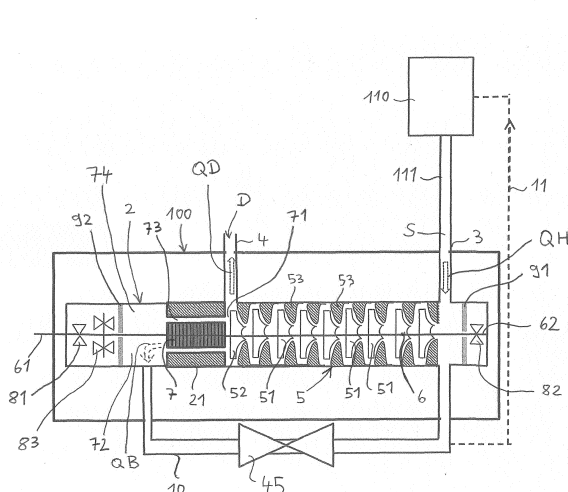
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(54) **ADJUSTING DISCHARGE FLOW OF A MULTISTAGE PUMP BY SETTING BALANCE DRUM CLEARANCE**

(57) A centrifugal pump for conveying a fluid is proposed, comprising a pump housing (2) with an inlet (3) at a suction side (S) and an outlet (4) at a discharge side (D), a hydraulic unit (5) with at least one impeller (51, 52) for conveying the fluid from the inlet (3) to the outlet (4), a shaft (6) for rotating the impeller (51, 52) about an axial direction (A), a balance drum (7) fixedly connected to the shaft (6) and arranged adjacent to the at least one impeller (51, 52), wherein the balance drum (7) defines a front side (71) facing the at least one impeller (51, 52) and a back side (72), wherein a relief passage (73) is provided between the balance drum (7) and a stationary part (21) configured to be stationary with respect to the

pump housing (2), wherein the relief passage (73) extends from the front side (71) to the back side (72), wherein a balance line (10) is provided, configured for discharging the fluid from the back side (72), wherein the hydraulic unit (5) is configured to generate a presettable hydraulic flow (QH), being larger than a presettable discharge flow (QD) passing through the outlet (4), wherein the relief passage (73) is configured such that a balance flow (QB) passes through the relief passage (73), and wherein the balance flow (QB) is adjusted to reduce the hydraulic flow (QH) to the discharge flow (QD). In addition, a method for controlling a discharge flow (QD) of a fluid is proposed.



Description

[0001] The invention relates to a centrifugal pump for conveying a fluid and to a method for controlling a discharge flow of a fluid conveyed by a centrifugal pump in accordance with the preamble of the independent claim of the respective category.

[0002] Centrifugal pumps for conveying a fluid, for example a liquid such as water, are used in many different industries. Examples are the oil and gas industry, the power generation industry, the chemical industry, the water industry or the pulp and paper industry. Centrifugal pumps have a hydraulic unit comprising at least one impeller and in many cases a volute or a diffuser. A shaft is provided for rotating the impeller(s). The at least one impeller may be configured for example as a radial impeller or as an axial or semi-axial impeller or as a helico-axial impeller. Furthermore, the impeller may be configured as an open impeller or as a closed impeller, where a shroud is provided on the impeller, said shroud at least partially covering the vanes of the impeller.

[0003] A centrifugal pump may be designed as a single stage pump having only one impeller mounted to the shaft or as a multistage pump comprising a plurality of impellers, wherein the impellers are arranged one after another on the shaft e.g. in an inline arrangement or in a back-to-back arrangement.

[0004] Many centrifugal pumps are provided with it at least one balancing device for at least partially balancing the axial thrust that is generated by the impeller(s) during operation of the pump. The balancing device reduces the axial thrust that is acting on the axial bearing or the thrust bearing. The balancing device may comprise a balance drum for at least partially balancing the axial thrust that is generated by the rotating impellers. The balance drum is fixedly connected to the shaft of the pump in a torque proof manner. In an inline arrangement of the impellers the balance drum is usually, arranged at the discharge side of the pump between the last stage impeller and a shaft sealing device. The balance drum defines a front side and a back side. The front side is the side facing the last stage impeller. The back side is the side facing the shaft sealing device. A relief passage is provided between the balance drum and a stationary part being stationary with respect to the pump housing. The back side is usually connected to the suction side or an intermediate stage of the pump by means of a balance line. During operation there is a leakage flow through the relief passage from the front side along the balance drum to the back side and from there through the balance line to the suction side or an intermediate stage. At the front side of the balance drum the high pressure or the discharge pressure prevails, and at the back side essentially the suction pressure prevails. The pressure difference between the front side and the back side results in a axial force or an axial thrust which is directed in the opposite direction as the axial thrust generated by the rotating impeller(s). Thus, the axial thrust that has to be carried by

the axial or thrust bearing is at least considerably reduced. Of course, the leakage flow along the balance drum results in a decrease of the hydraulic performance or efficiency of the pump.

[0005] In a back-to-back arrangement of the impellers the balance drum is usually arranged between an intermediate stage impeller and the drive end or the non-drive end of the shaft. In any case the pressure at the front side is higher than the pressure at the back side.

[0006] The performance curve or pump curve of a centrifugal pump for a particular speed is usually given by the H-Q-curve showing the relationship between the head H generated by the pump and the flow Q generated by the pump. The head H is also referred to as the discharge pressure at the outlet of the pump. In most applications the centrifugal pump is operated at or very close to the best efficiency point, which is the point on the H-Q-curve, where the hydraulic efficiency of the pump is at maximum.

[0007] Classically, the discharge flow of a centrifugal pump for a given head H is defined and adjusted by the geometry of the hydraulic unit, such as the geometry of the impeller(s) and/or the geometry of the diffuser, e.g. the diffuser throat(s), or the geometry of the volute(s). Thus, for generating a given discharge flow the geometry of the hydraulic unit is specifically adapted and adjusted. Therefore, changes in the desired discharge flow typically require an adaption of the geometry of the hydraulic unit of the pump. This issue is addressed by the invention.

[0008] It is therefore an object of the invention to propose a centrifugal pump for conveying a fluid, which allows to easily modify the discharge flow for a given head. In addition, it is an object of the invention to propose a method for controlling a discharge flow of a fluid conveyed by a centrifugal pump in a simple manner.

[0009] The subject matter of the invention satisfying these objects is characterized by the features of the respective independent claims.

[0010] Thus, according to the invention, a centrifugal pump for conveying a fluid is proposed, comprising a pump housing with an inlet at a suction side and an outlet at a discharge side, a hydraulic unit with at least one impeller for conveying the fluid from the inlet to the outlet, a shaft for rotating the impeller about an axial direction, a balance drum fixedly connected to the shaft and arranged adjacent to the at least one impeller, wherein the balance drum defines a front side facing the at least one impeller and a back side, wherein a relief passage is provided between the balance drum and a stationary part configured to be stationary with respect to the pump housing, wherein the relief passage extends from the front side to the back side, wherein a balance line is provided, configured for discharging the fluid from the back side, wherein the hydraulic unit is configured to generate a presetable hydraulic flow, being larger than a presetable discharge flow passing through the outlet, wherein the relief passage is configured such that a balance flow passes through the relief passage, and wherein the bal-

ance flow is adjusted to reduce the hydraulic flow to the discharge flow.

[0011] According to the invention, the balance flow passing along the balance drum through the relief passage is used to reduce the hydraulic flow, which is generated by the hydraulic unit, to the discharge flow passing through the outlet of the pump. This measure has the considerable advantage that a universal hydraulic unit may be used for generating different discharge flows. If a second centrifugal pump is required, which shall generate a different discharge flow with preferably the same head than a first centrifugal pump, it is no longer necessary to modify the geometry of the hydraulic unit of the second centrifugal pump, i.e. for the second centrifugal pump the same hydraulic unit may be used as for the first centrifugal pump. Rather than modifying the hydraulic flow generated by the hydraulic unit to change the discharge flow, the balance flow is modified to change the discharge flow. A change of the balance flow may be achieved for example by modifying the geometry of the relief passage extending along the balance drum. In particular, the length of the balance drum in the axial direction and therewith the length of the relief passage may be changed and/or the width of the relief passage in the radial direction perpendicular to the axial direction is modified, i.e. the distance between the radially outer surface of the balance drum and the stationary part delimiting the relief passage.

[0012] Since the universal hydraulic unit may be used to produce different discharge flows, it is possible to realize various pump curves (H-Q-curves) with the same hydraulic unit.

[0013] Preferably, the balance line is configured for connecting the back side with the suction side. To this end the balance line may be in fluid communication with the inlet of the centrifugal pump, e.g. open into the inlet, or the balance line is connected with a reservoir such as a tank at the suction side, from where the fluid is supplied to the inlet.

[0014] According to a preferred embodiment the centrifugal pump comprises a flow control element, which is configured for controlling the balance flow. Thus, for changing the discharge flow of the centrifugal pump it is only necessary to modify or to exchange the flow control element in order to change the balance flow.

[0015] Preferably, the flow control element is provided in the balance line, because this is a very simple measure to control the balance flow through the balance line.

[0016] Furthermore, it is advantageous when the flow control element is arranged outside of the pump housing, so that the flow control element can be easily accessed.

[0017] Particularly preferred, the flow control element is configured as an adjustable valve. This measure has the advantage that the discharge flow may be tuned or adjusted in a very simple manner, namely by only adjusting the flow control element for modifying the balance flow. Furthermore, this measure allows for less tight tolerances with respect to the manufacturing of the hydraulic

components such as the diffuser(s) or the impeller(s). It might even render possible to omit machining operations, for example because the cast accuracy is sufficient. A further advantage is that the discharge flow of the centrifugal pump may be tuned without installing a throttle or any other flow restricting device directly to the discharge. Thus, the requirements of international norms such as API 610 are fulfilled.

[0018] The tuning of the discharge flow by means of modifying the balance flow is in particular advantageous for applications requiring a very low discharge flow and high heads (discharge pressures). In such applications the sensitivity of the discharge flow both on the geometry of the hydraulic unit and on the balance flow is very high. By modifying the balance flow, i.e. only one parameter, it becomes possible to adjust the discharge flow to the desired value.

[0019] Furthermore, it is preferred that the flow control element is configured for changing the balance flow during operation of the centrifugal pump. This measure allows for a readjustment of the discharge flow during operation of the centrifugal pump.

[0020] According to a preferred embodiment the pump is configured as a multistage pump having a plurality of impellers, wherein the impellers are arranged one after another on the shaft (6).

[0021] Furthermore, it is preferred that the pump is configured as a between-bearing pump.

[0022] In particular, the pump may be configured as a barrel type pump comprising an outer barrel casing, in which the pump housing is arranged.

[0023] In addition, according to the invention a method is proposed for controlling a discharge flow of a fluid conveyed by a centrifugal pump having a pump housing with an inlet at a suction side and an outlet at a discharge side, comprising the steps of: providing a hydraulic unit with at least one impeller for conveying the fluid from the inlet to the outlet,

providing a shaft for rotating the impeller about an axial direction,

providing a balance drum fixedly connected to the shaft and arranged adjacent to the at least one impeller, wherein the balance drum defines a front side facing the at least one impeller and a back side,

providing a relief passage between the balance drum and a stationary part configured to be stationary with respect to the pump housing, wherein the relief passage extends from the front side to the back side,

providing a balance line, configured for discharging the fluid from the back side, defining the discharge flow, configuring the hydraulic unit to generate a presetable hydraulic flow, being larger than the discharge flow passing through the outlet, and

configuring the relief passage such that a balance flow passes through the relief passage, wherein the balance flow is adjusted to reduce the hydraulic flow to the discharge flow.

[0024] The explanations given with respect to the cen-

trifugal pump according to the invention also apply to the method according to the invention in an analogous manner.

[0025] By the same reasons as already explained with respect to the centrifugal pumps the following steps are preferred:

- the balance flow is controlled by means of a flow control element;
- the flow control element is arranged outside of the pump housing;
- changing the balance flow during operation of the centrifugal pump.

[0026] As a further option it is also possible to remotely controlling the balance flow.

[0027] Further advantageous measures and embodiments of the invention will become apparent from the dependent claims.

[0028] The invention will be explained in more detail hereinafter both with respect to the apparatus and with respect to the method with reference to embodiments of the invention and with reference to the drawings. There are shown in a schematic representation:

Fig. 1: a schematic cross-sectional view of an embodiment of a centrifugal pump according to the invention, and

Fig. 2: a cross-sectional view illustrating a configuration of the balance drum and the connecting line.

[0029] Fig. 1 shows a schematic cross-sectional view of an embodiment of a centrifugal pump according to the invention, which is designated in its entity with reference numeral 1. The pump 1 is designed as a centrifugal pump for conveying a fluid, for example a liquid such as water.

[0030] The centrifugal pump 1 comprises a pump housing 2 having an inlet 3 and an outlet 4 for the fluid to be conveyed. The inlet 3 is arranged at a suction side S, where a suction pressure prevails, and the outlet 4 is arranged at a discharge side D, where a discharge pressure prevails. The suction pressure is also referred to as low pressure, and the discharge pressure is also referred to as high pressure. The centrifugal pump 1 further comprises a hydraulic unit 5 with at least one impeller 51, 52 for conveying the fluid from the inlet 3 to the outlet 4 as well as a shaft 6 for rotating each impeller 51, 52 about an axial direction A. The axial direction A is defined by the axis of the shaft 6. Each impeller 51 is mounted to the shaft 6 in a torque proof manner. The shaft 6 has a drive end 61, which may be connected to a drive unit (not shown) for driving the rotation of the shaft 6 about the axial direction A. The drive unit may comprise, for example, an electric motor. The other end of the shaft 6 is

referred to as non-drive end 62.

[0031] A direction perpendicular to the axial direction A is referred to as radial direction.

[0032] In the following description reference is made by way of example to an embodiment, which is suited for many applications, namely that the centrifugal pump 1 is configured as a multistage pump 1 having a plurality of impellers 51, 52, wherein the impellers 51, 52 are arranged one after another on the shaft 6. The reference numeral 52 designates the last stage impeller 52, which is the impeller 52 closest to the outlet 4. The last stage impeller 52 pressurizes the fluid to the discharge pressure. The embodiment shown in Fig. 1 has nine stages, which has to be understood exemplary. The plurality of impellers 51, 52 may be arranged in an inline configuration as shown in Fig. 1 or in a back-to-back configuration. Each impeller 51, 52 is designed as a radial impeller.

[0033] The hydraulic unit 5 further comprises a plurality of stationary diffusers 53, which are stationary with respect to the pump housing 2. Between each pair of adjacent impellers 51, 52 a diffuser 53 is provided for redirecting the generally radial flow exiting from the particular impeller 51 in a generally axial direction A towards the next stage impeller 51, 52. The hydraulic unit 5 comprises the entirety of all impellers 51, 52 and all diffusers 53.

[0034] The multistage centrifugal pump 1 shown in Fig. 1 is designed as a horizontal pump, meaning that during operation the shaft 6 is extending horizontally, i.e. the axial direction A is perpendicular to the direction of gravity. In particular, the centrifugal pump 1 shown in Fig. 1 may be designed as a horizontal barrel casing multistage pump 1, i.e. as a double-casing pump. The multistage pump 1 may be designed, for example, as a pump 1 of the pump type BB5 according to API 610. When configured as a BB5 type pump, the centrifugal pump 1 comprises an outer barrel casing 100, in which the pump housing 2 is arranged.

[0035] It has to be understood that the invention is not restricted to this type of centrifugal pump 1. In other embodiments, the centrifugal pump may be configured without an outer barrel casing, for example as a BB4 type pump, or as an axially split multistage pump, or as a single stage pump, or as a vertical pump, meaning that during operation the shaft 6 is extending in the vertical direction, which is the direction of gravity, or as any other type of centrifugal pump.

[0036] The centrifugal pump 1 comprises bearings on both sides of the plurality of impellers 51, 52 (with respect to the axial direction A), i.e. the centrifugal pump 1 is designed as a between-bearing pump. A first radial bearing 81, a second radial bearing 82 and an axial bearing 83 are provided for supporting the shaft 6. The first radial bearing 81 is arranged adjacent to the drive end 61 of the shaft 6. The second radial bearing 82 is arranged adjacent to or at the non-drive end 62 of the shaft 6. The axial bearing 83 is arranged between the plurality of impellers 51, 52 and the first radial bearing 81 adjacent to the first radial bearing 81. The bearings 81, 82, 83 are

configured to support the shaft 6 both in the axial direction A and in a radial direction, which is a direction perpendicular to the axial direction A. The radial bearings 81 and 82 are supporting the shaft 6 with respect to the radial direction, and the axial bearing 83 is supporting the shaft 6 with respect to the axial direction A. The first radial bearing 81 and the axial bearing 83 are arranged such that the first radial bearing 81 is closer to the drive end 61 of the shaft 6. Of course, it is also possible to exchange the position of the first radial bearing 81 and the axial bearing 83, i.e. to arrange the first radial bearing 81 between the axial bearing 83 and the plurality of impellers 51, 52, so that the axial bearing 83 is closer to the drive end 61 of the shaft 6.

[0037] A radial bearing, such as the first or the second radial bearing 81 or 82 is also referred to as a "journal bearing" and an axial bearing, such as the axial bearing 83, is also referred to as an "thrust bearing". The first radial bearing 81 and the axial bearing 83 may be configured as separate bearings as shown in Fig. 1, but it is also possible that the first radial bearing 81 and the axial bearing 83 are configured as a single combined radial and axial bearing supporting the shaft both in radial and in axial direction.

[0038] The second radial bearing 82 is supporting the shaft 6 in radial direction. In the embodiment shown in Fig. 1, there is no axial bearing provided at the non-drive end 62 of the pump shaft 6. Of course, in other embodiments it is also possible that an axial bearing for the shaft 6 is provided at the non-drive end 62. In embodiments, where an axial bearing is provided at the non-drive end 62, a second axial bearing may be provided at the drive end 61 or the drive end 61 may be configured without an axial bearing.

[0039] The centrifugal pump 1 further comprises two sealing devices, namely a first sealing device 91 for sealing the shaft 6 at the suction side S and a second sealing device 92 for sealing the shaft 6 at the discharge side D. With respect to the axial direction A the first sealing device 91 is arranged between the hydraulic unit 5 and the second radial bearing 82, and the second sealing device 92 is arranged between the last stage impeller 52 and the axial pump bearing 83. Both sealing devices 91, 92 seal the shaft 6 against a leakage of the fluid along the shaft 6 e.g. into the environment. Furthermore, by the sealing devices 91 and 92 the fluid may be prevented from entering the bearings 81, 82, 83. Preferably each sealing device 91, 92 comprises a mechanical seal. Mechanical seals are well-known in the art in many different embodiments and therefore require no detailed explanation. In principle, a mechanical seal is a seal for a rotating shaft 6 and comprises a rotor part fixed to the shaft 6 and rotating with the shaft 6, as well as a stationary stator part fixed with respect to the pump housing 2. During operation the rotor part and the stator part are sliding along each other - usually with a liquid as lubricant and coolant there between - for providing a sealing action to prevent the fluid from escaping to the environment or

entering the bearings 81, 82, 83. In many embodiments a separate bearing isolator is provided which prevents liquids or solids to enter the bearings 81, 82, 83. In such embodiments where separate bearing isolators are provided, the sealing devices 91, 92, e.g. the mechanical seals prevent the fluid from leaking into the environment.

[0040] The centrifugal pump 1 further comprises a balance drum 7 for at least partially balancing the axial thrust that is generated by the impellers 51, 52 during operation of the centrifugal pump 1. The balance drum 7 is fixedly connected to the shaft 6 in a torque proof manner. The balance drum 7 is arranged at the discharge side D between the last stage impeller 52 and the second sealing device 92. The balance drum 7 defines a front side 71 and a back side 72. The front side 71 is the side facing the last stage impeller 52. The back side 72 is the side facing the second sealing device 92. The balance drum 7 is surrounded by a stationary part 21, so that a relief passage 73 is formed between the radially outer surface of the balance drum 7 and the stationary part 21. The stationary part 21 is configured to be stationary with respect to the pump housing 2. The relief passage 73 forms an annular gap between the outer surface of the balance drum 7 and the stationary part 21 and extends from the front side 71 to the back side 72. The front side 71 is in fluid communication with the outlet 4, so that the axial surface of the balance drum 7 facing the front side 71 is exposed essentially to the discharge pressure prevailing at the outlet 4 during operation of the pump 1. Of course, due to smaller pressure losses caused by the fluid communication between the outlet 4 and the balance drum 7 the pressure prevailing at the axial surface of the balance drum 7 facing the front side 71 may be somewhat smaller than the discharge pressure. However, the considerably larger pressure drop takes place over the balance drum 7. At the back side 72 a chamber 74 is provided, which is connected by a balance line 10 with the suction side S, e.g. with the inlet 3. The pressure in the chamber 74 at the back side 72 is somewhat larger than the suction pressure due to the pressure drop over the balance line 10 but considerably smaller than the discharge pressure.

[0041] Since the front side 71 is exposed essentially to the discharge pressure at the outlet 4, a pressure drop exists over the balance drum 7 resulting in a force that is directed to the left side according to the representation in Fig. 1 and therewith counteracts the axial thrust generated by the impellers 51, 52 during operation of the pump 1.

[0042] The balance line 10 is provided for recirculating the fluid from the chamber 74 at the back side 72 to the suction side S. A part of the pressurized fluid passes from the front side 71 through the relief passage 73 to the back side 72, enters the balance line 10 and is recirculated to the suction side S of the centrifugal pump 1. The balance line 10 constitutes a flow connection between the back side 72 and the suction side S at the pump inlet 3. The balance line 10 may be arranged - as shown in Fig. 1 -

outside the pump housing 2 and outside the barrel casing 100. In other embodiments the balance line 10 may be designed as internal line completely extending within the pump housing 2. In still other embodiments the balance line may be arranged outside the pump housing 2 and inside the barrel casing 100.

[0043] In other embodiments the balance line 10 may be connected with a reservoir 110 such as a tank 110 at the suction side S, from where the fluid is supplied to the inlet 3 by means of a supply line 111. This alternative is indicated in Fig. 1 by the dashed line 11. Thus, the fluid is recirculated from the chamber 74 at the back side 72 to the tank 110.

[0044] In still other embodiments the balance line is connected to an intermediate stage, for example to the discharge side of one of the impellers 51 or to one of the diffusers 53, so that the pressurized fluid is recirculated from the chamber 74 at the back side 72 to one of the intermediate stages of the pump.

[0045] The hydraulic unit 5 is configured to generate a presettable hydraulic flow QH. The hydraulic flow QH is the flow, which leaves the last stage impeller 52 (see also Fig. 2). In case there is no intermediate take-off at any of the impellers 51, the hydraulic flow QH equals the flow, which is passing through the inlet 3 at the suction side S, where the suction pressure prevails. The generated hydraulic flow QH depends on the geometry of the hydraulic unit 5, e.g. the geometry of the impeller(s) 51, 52 and/or the geometry of the diffuser(s) 53, in particular the diffuser throat.

[0046] The centrifugal pump 1 shall generate a presettable discharge flow QD at the discharge side D, where the discharge pressure prevails. The discharge flow QD is the flow, which passes through the outlet 4 of the centrifugal pump 1.

[0047] The hydraulic unit 5 is configured to generate an hydraulic flow QH, which is larger than the desired discharge flow QD.

[0048] According to the invention, a balance flow QB, which is the flow passing through the relief passage 73, is adjusted to reduce the hydraulic flow QH to the discharge flow QD. This will be explained in more detail hereinafter.

[0049] For a better understanding Fig. 2 shows a cross-sectional view illustrating a configuration of the balance drum 7 and the balance line 10. Since it is sufficient for the understanding, in Fig. 2 only two impellers 51, 52 are shown, which may be for example the first stage impeller 51 and the last stage impeller 52 of a two stage pump 1. It has to be noted that there may be more impellers 51, so that the centrifugal pump is configured as a multistage pump 1 having more than two stages. The balance line 10 is represented partially as a single line in Fig. 2, wherein the direction of flow through the balance line 10 is indicated by the arrows in the balance line 10 without reference numeral. The flow of the fluid flowing through the pump 1 is indicated in Fig. 2 by the dashed arrows without reference numeral.

[0050] After the fluid has passed the last stage impeller 52 the hydraulic flow QH is divided into the discharge flow QD, which leaves the centrifugal pump 1 through the outlet 4, and the balance flow QB, which passes through the relief passage 73 into the chamber 74 at the back side 72. The balance flow 10 is recycled from the chamber 74 through the balance line 10 to the inlet 3 at the low pressure side L or to the reservoir 110, respectively.

[0051] The balance flow QB is adjusted such that it equals the difference between the hydraulic flow QH and the discharge flow QD. In other words, the discharge flow QD is tuned to the desired value by adjusting the balance flow QB.

[0052] The balance flow QB may be adjusted by the geometry of the relief passage 73, which constitutes a throttle. In particular, the balance flow QB can be adjusted by the length L of the relief passage 73, which is the extension of the relief passage 73 in the axial direction A, and the width W of the relief passage 73, which is the extension of the relief passage in the radial direction. The length L is given by the extension of the balance drum 7 in the axial direction A. The width W is given by the clearance between the balance drum 7 and the stationary part 26. Thus, by adjusting the length L and/or the width W of the relief passage 73 the balance flow QB may be adjusted such that the balance flow corresponds to the difference between the hydraulic flow QH generated by the hydraulic unit 5 and the desired discharge flow QD passing through the outlet 4 of the centrifugal pump.

[0053] According to a preferred design the centrifugal pump 1 comprises in addition to the relief passage 73 a flow control element 45, which is configured for controlling the balance flow QB. The flow control element 45 may be designed as a throttle or as an orifice or as a valve such as a flow control valve or any other adjustable valve.

[0054] Preferably the flow control element 45 is arranged in the balance line 10. Furthermore, it is preferred that the flow control element 45 is arranged outside of the pump housing 2. In embodiments, where the centrifugal pump 1 comprises the outer barrel casing 100, the flow control element is preferably arranged outside the outer barrel casing 100. Providing the flow control element 45 outside the pump housing 2 or outside the outer barrel casing 100 has the considerable advantage that the flow control element 45 may be modified or replaced by another flow control element in a very simple manner.

[0055] In particular, the flow control element 45 may be configured as an adjustable throttle or as an adjustable valve. This renders possible that the balance flow may be modified online, i.e. when the centrifugal pump 1 is in operation. Thus, the discharge flow QD may be modified or tuned during operation of the centrifugal pump 1 by modifying the balance flow by means of the flow control element 45.

[0056] Furthermore, the flow control element may be configured for a remote control, so that the discharge flow QD may be tuned by means of modifying the balance

flow from a remote location, i.e. without physically contacting the centrifugal pump 1.

Claims

1. A centrifugal pump for conveying a fluid, comprising a pump housing (2) with an inlet (3) at a suction side (S) and an outlet (4) at a discharge side (D), a hydraulic unit (5) with at least one impeller (51, 52) for conveying the fluid from the inlet (3) to the outlet (4), a shaft (6) for rotating the impeller (51, 52) about an axial direction (A), a balance drum (7) fixedly connected to the shaft (6) and arranged adjacent to the at least one impeller (51, 52), wherein the balance drum (7) defines a front side (71) facing the at least one impeller (51, 52) and a back side (72), wherein a relief passage (73) is provided between the balance drum (7) and a stationary part (21) configured to be stationary with respect to the pump housing (2), wherein the relief passage (73) extends from the front side (71) to the back side (72), and wherein a balance line (10) is provided, configured for discharging the fluid from the back side (72) **characterized in that** the hydraulic unit (5) is configured to generate a presettable hydraulic flow (QH), being larger than a presettable discharge flow (QD) passing through the outlet(4), and **in that** the relief passage (73) is configured such that a balance flow (QB) passes through the relief passage (73), wherein the balance flow (QB) is adjusted to reduce the hydraulic flow (QH) to the discharge flow (QD).
2. A centrifugal pump in accordance with claim 1, wherein the balance line (10) is configured for connecting the back side (72) with the suction side (S).
3. A centrifugal pump in accordance with anyone of the preceding claims, comprising a flow control element (45), which is configured for controlling the balance flow (QB).
4. A centrifugal pump in accordance with anyone of the preceding claims, wherein the flow control element (45) is provided in the balance line (10).
5. A centrifugal pump in accordance with claim 3 or claim 4, wherein the flow control element (45) is arranged outside of the pump housing (2).
6. A centrifugal pump in accordance with anyone of claims 3-5, wherein the flow control element (45) is configured as an adjustable valve.
7. A centrifugal pump in accordance with anyone of claims 3-6, wherein the flow control element (45) is configured for changing the balance flow (QB) during operation of the centrifugal pump (1).

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8. A centrifugal pump in accordance with anyone of the preceding claims, wherein the pump is configured as a multistage pump having a plurality of impellers (51, 52), wherein the impellers (51, 52) are arranged one after another on the shaft (6).

9. A centrifugal pump in accordance with anyone of the preceding claims, configured as a between-bearing pump.

10. A centrifugal pump in accordance with anyone of the preceding claims, comprising an outer barrel casing (100), in which the pump housing (2) is arranged.

11. A method for controlling a discharge flow (QD) of a fluid conveyed by a centrifugal pump having a pump housing (2) with an inlet (3) at a suction side (S) and an outlet (4) at a discharge side (D), comprising the steps of:

providing a hydraulic unit (5) with at least one impeller (51, 52) for conveying the fluid from the inlet (3) to the outlet (4),

providing a shaft (6) for rotating the impeller (51, 52) about an axial direction (A),

providing a balance drum (7) fixedly connected to the shaft (6) and arranged adjacent to the at least one impeller (51, 52), wherein the balance drum (7) defines a front side (71) facing the at least one impeller (51, 52) and a back side (72), providing a relief passage (73) between the balance drum (7) and a stationary part (21) configured to be stationary with respect to the pump housing (2), wherein the relief passage (73) extends from the front side (71) to the back side (72), and

providing a balance line (10), configured for discharging the fluid from the back side (72), **characterized by** the steps of:

defining the discharge flow (QD), configuring the hydraulic unit (5) to generate a presettable hydraulic flow (QH), being larger than the discharge flow (QD) passing through the outlet(4), and configuring the relief passage (73) such that a balance flow (QB) passes through the relief passage (73), wherein the balance flow (QB) is adjusted to reduce the hydraulic flow (QH) to the discharge flow (QD).

12. A method in accordance with claim 11, wherein the balance flow is controlled by means of a flow control element (45).

13. A method in accordance with claim 12, wherein the flow control element (45) is arranged outside of the pump housing (2).

14. A method in accordance with anyone of claims 11-13, comprising the step of remotely controlling the balance flow (QB).

15. A method in accordance with anyone of claims 11-14, comprising the step of changing the balance flow (QB) during operation of the centrifugal pump (1).

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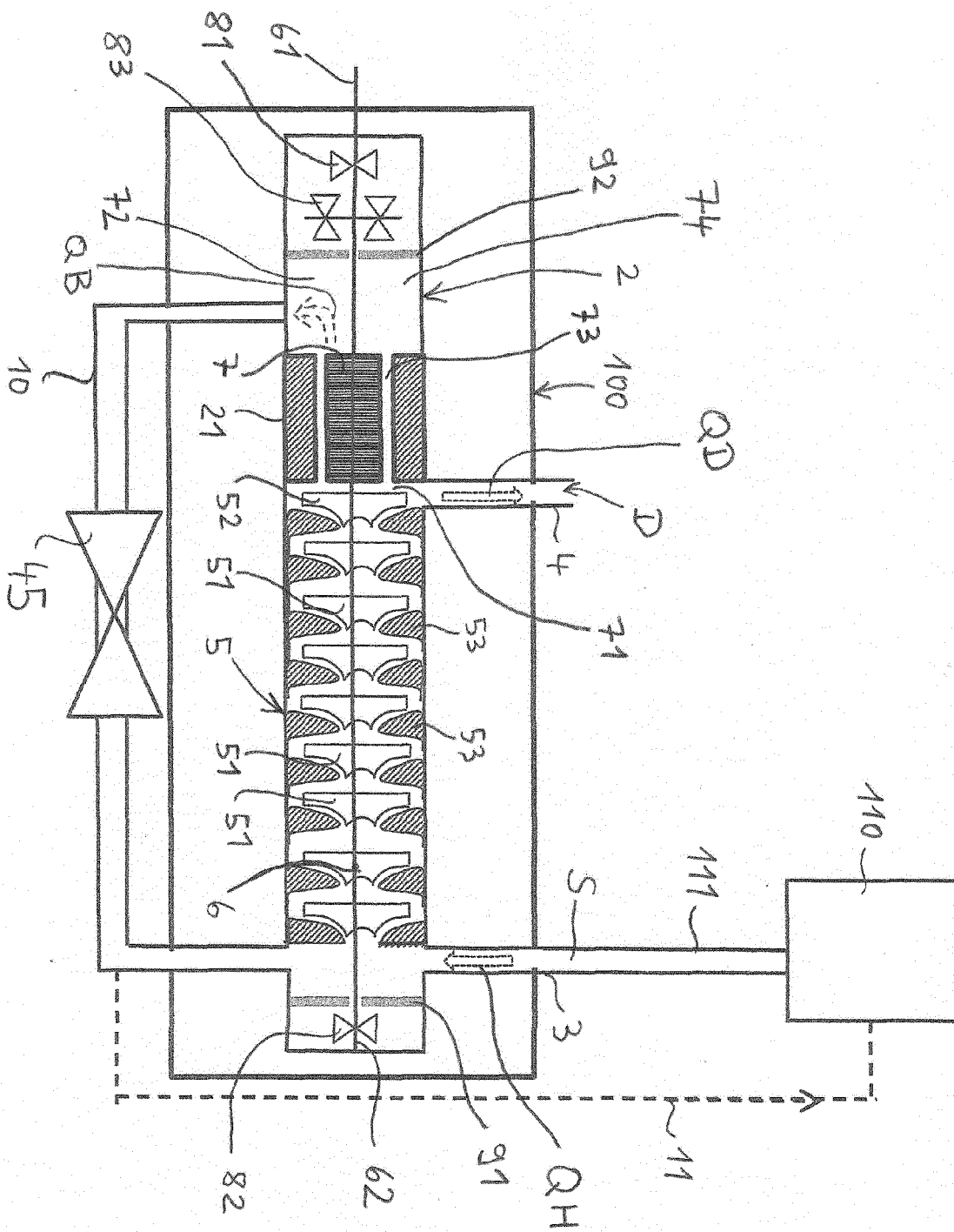
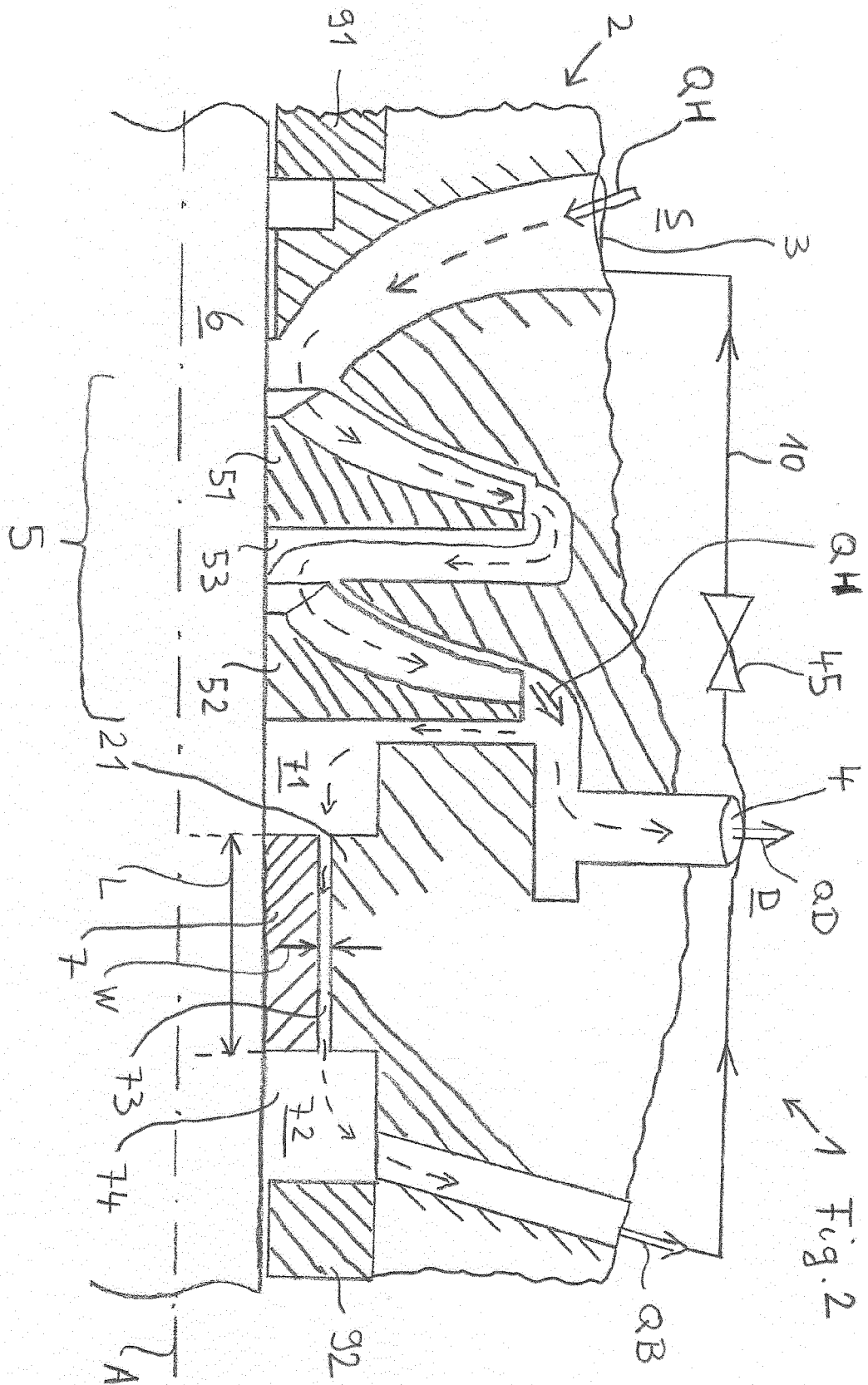


Fig. 1
← 1





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The members are as contained in the European Patent Office EDP file on
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