

TWO-STAGE CENTRIFUGAL PUMP

Technical Field

[0001] This disclosure relates in general to a two-stage centrifugal pump, that is, comprising at least two impellers provided with respective arrays of blades, each of which is associated with fixed pipes and used for the suction and discharge of a fluid, generally a liquid.

Background of the Disclosure

[0002] Centrifugal pumps are configured to exert work on a fluid which translates into pressurized and kinetic energy.

[0003] Centrifugal pumps generally have a rotary part, also called impeller, which in use can be caused to rotate around a rotation shaft.

[0004] The impeller is provided with a plurality of blades associated with a hub and defining between them mobile pipes in which the fluid flows with a continuous motion.

[0005] The impeller is closed inside a case in which the fixed pipes are made for the inlet and outlet of the fluid from the impeller.

[0006] The case comprises a suction pipe to feed the fluid to the impeller and an outlet pipe to discharge the fluid from the impeller.

[0007] The outlet pipe of a centrifugal pump is known as a volute which, in some cases, can also be provided with an array of blades which takes the name of diffuser.

[0008] The transformation of the kinetic energy into pressure energy, due to the speed of the fluid, is achieved in the diffuser.

[0009] Depending on the requirements of the application, generally connected to the parameters of flow rate and pressure, the impellers can assume different configurations.

[0010] It is also known to classify centrifugal pumps into:

- slow, radial pumps for low flow rates and high pressures;
- fast radial pumps for high flow rates and low pressures;
- medium radial pumps for intermediate conditions between slow radial centrifugal pumps and fast radial pumps.

[0011] These types of pumps differ from each other in the particular configuration of the blades associated with them. In particular, in the passage from a slow radial pump to a medium and a fast one, the blades of the impeller have a development that gradually passes from mainly radial to mainly axial.

[0012] It is also known that the type of blade is chosen for the particular application required and is dictated by the conditions of the fluid, generally pressure and speed, available in the suction pipe, and by the conditions required for delivery.

[0013] A wrong choice of the type of blades can entail a drastic reduction in the performance of the pump due to known cavitation phenomena.

[0014] More and more frequently, the suction conditions available in a plant lead to the choice of a so-called slow pump, and therefore, in order to guarantee the performance required for delivery, the machine has to be adequately sized, increasing the geometric sizes and/or preparing the machine with an adequate number of stages.

[0015] In fact, pumps with several stages are also known, that is, comprising successive arrays of blades of the impeller, separated by fixed reciprocal connection pipes.

[0016] Known multistage pumps comprise two or more impellers located in series with each other so that the stream of fluid exiting from the first impeller enters into the second impeller. The impellers are sometimes mounted on a common rotation shaft, they are both lapped substantially by the same stream of fluid and the pressure of the fluid exiting from the second impeller is substantially double that exiting from the first impeller, except for load losses.

[0017] The fact that the impellers are mounted in series on the same rotation shaft determines a considerable increase in the bulk sizes, at least in the direction of the length of the shaft, which may conflict with possible application requirements.

[0018] Since the impellers are mounted on a common rotation shaft, they rotate at the same angular speed.

[0019] Because the impellers have the same rotation speed, in some applications this imposes a limit on the performance, that is, on the conditions of pressure or the speed of the fluid that are to be obtained for delivery to the machine.

[0020] Due to this condition, the performance of the pump is greatly limited, and also because of restrictive suction conditions which are present in the suction pipe of the pump and which are usually characterized by low NPSHA values (Net Positive Suction Head Available), observance of which is required so that no problems of cavitation can occur in the operation of the pump.

[0021] It is known to provide multi-stage pumps with two or more impellers each mounted on separate shafts. However, such pumps have only been suitable for use in a narrow range of operating conditions.

Summary

[0022] In a first aspect there is provided a two-stage centrifugal pump comprising:

- a first stage provided with a first impeller; and a second stage provided with a second impeller and hydraulically connected to the first stage;

- the first impeller being mounted on a first shaft and the second impeller being mounted on a second shaft distinct from said first shaft;

wherein the first stage and the second stage are located in a support body, the support body being provided with a first chamber and a second chamber in which the respective first impeller and the second impeller are contained; and

wherein the support body comprises a single casing provided with a first cavity and a second cavity that each define respective portions of said first chamber and said second chamber; and

wherein in at least one of either the first cavity or the second cavity, one or more adaptors are mounted, in use to adapt the geometry of the first chamber and/or the second chamber to the type and size of impeller adopted.

[0023] This embodiment makes the function of the first stage of the pump independent from that of the second stage, allowing greater flexibility and adaptability in the operation of the pump for different applications and for different fields in which it will be used. With this configuration it is possible to satisfy increasingly restrictive suction conditions, and also the conditions required

for delivery. The design allows the operator to change the geometric characteristics of the pump and also on the speed of rotation of the individual impellers for maximum flexibility of use.

[0024] . The fact that the casing is made in a single body allows a reduction in the number of components that make up the pump, and also can simplify the assembly operation thereof.

[0025] By use of adaptors, it is possible to construct a single support body, or pump body, that can be used to cover a wide operating range, required for many specific applications. This embodiment also allows for a simplification of manufacturing operations, since there is no need to maintain multiple dedicated apparatus, such as casting molds, which would otherwise be needed to manufacture different pump body sizes for use in different applications.

[0026] In yet other embodiments, the first shaft and the second shaft have respective axes of rotation arranged parallel to each other.

[0027] In still other embodiments, each of the first shaft and second shaft is connected to a respective actuation member selected from between a motor, at least one gear or a combination thereof.

[0028] In other embodiments, the pump includes at least a gearbox that connects the actuation member of the first shaft to the actuation member of the second shaft.

[0029] In still other embodiments, the pump includes a drive member connected to the gearbox to make both the first impeller and the second impeller rotate.

[0030] In other embodiments, the gearbox obtains a reduction and/or multiplication of the angular rotation speed of the first shaft with respect to that of the second shaft.

[0031] In other embodiments, the gearbox includes a reduction unit.

[0032] In other embodiments, one or more of the adaptors also includes a support element to support and allow the rotation of either the first or second impellers.

[0033] In some embodiments, the support body defines a suction channel and a delivery channel through which the stream of fluid is respectively introduced into, and discharged from, the pump.

[0034] In some embodiments, the support body includes a connection channel which hydraulically connects the second stage to the first stage.

[0035] In a second aspect, there is provided a pump system including a pump according to the first aspect, and a range of adaptors to adapt the geometry of the first chamber and/or the second chamber to suit the type and size of a range of impellers and/or diffusers.

[0036] In some embodiments, the pump system further includes a range of gears which can be selected to define the angular speed of said first shaft with respect to that of said second shaft.

[0037] In a third aspect there is provided a method of configuring a centrifugal pump,

the pump comprising:

- a first stage provided with a first impeller; and
 - a second stage provided with a second impeller and hydraulically connected to the first stage;
 - the first impeller being mounted on a first shaft and the second impeller being mounted on a second shaft distinct from said first shaft;
- wherein the first stage and the second stage are located in a support body, the support

body being provided with a first chamber and a second chamber in which the respective first impeller and the second impeller are contained; and

wherein the support body comprises a single casing provided with a first cavity and a second cavity that each define respective portions of said first chamber and said second chamber; and

wherein the method includes the steps of:

- adopting an impeller of a particular type or size for use in each of the first and second chamber; and
- selecting one or more adaptors for mounting in at least one of either the first cavity or the second cavity, in use to adapt the geometry of the first chamber and/or the second chamber to the type and size of impeller adopted.

[0038] In some embodiments, the method further includes the step of selecting at least one gear from a range of gears to define the angular speed of said first shaft with respect to that of said second shaft.

[0039] Other aspects, features, and advantages will become apparent from the following detailed description when taken in conjunction with the accompanying drawings, which are a part of this disclosure and which illustrate, by way of example, principles of the inventions disclosed.

Description of the Figures

[0040] The accompanying drawings facilitate an understanding of the various embodiments.

[0041] Figure 1 is a schematic representation, in section, of an embodiment of a two-stage centrifugal pump in accordance with this disclosure.

[0042] Figure 2 is a schematic representation, in section, of another embodiment of a two-stage centrifugal pump in accordance with this disclosure.

[0043] Figure 3 is a schematic representation, in section, of another embodiment of a two-stage centrifugal pump in accordance with this disclosure; and

[0044] Figure 4 is a rear view of the pump of Figure 3 with the gearbox removed.

Detailed Description

[0045] With reference to Figures 1, 2 and 3, a two-stage centrifugal pump is indicated in its entirety by the reference number 10. In each Figure, the same reference numerals have been used to denote like components.

[0046] The pump 10 comprises a first stage 11 and a second stage 12 which is hydraulically connected to the first stage 11 - that is, the second stage 12 is configured to receive the fluid processed by the first stage 11, and to further increase the energy thereof, both in terms of pressure and in terms of speed (velocity).

[0047] The first stage 11 and the second stage 12 respectively comprise a first impeller 13 and a second impeller 14. The first impeller 13 and the second impeller 14 are each provided with a respective array of blades. The first impeller 13 and the second impeller 14 are mounted respectively on a first shaft 15 and on a second shaft 16, distinct from each other. The first shaft 15 and the second shaft 16 have respective axes of rotation X1 and respectively X2, which are

located parallel to each other. Use of two-stage pump means that the overall bulk size of the pump 10 is reduced, as well as permitting the optimization of the distribution of its various components, as will be demonstrated.

[0048] Each of the first shaft 15 and second shaft 16 is connected to a respective actuation member 17a, 17b, for example at least one gear. The actuation members 17a, 17b are configured to make the respective first shaft 15 and the second shaft 16 be able to rotate at different rotation speeds, in response to drive energy from a motor.

[0049] In one possible solution, not shown in the drawings, it may be provided that the first shaft 15 and the second shaft 16 are driven by respective drive members selectively rotatable independently from each other. In another embodiment, the drive members can be governed by synchronizer devices to synchronize the operation of the first shaft 15 and the second shaft 16. Such an arrangement allows one stage of the pump 10 to operate independently from, or in synchronization with, the other pump stage, in order to obtain the required performance values.

[0050] According to the embodiments shown in Figures 1, 2 and 3, the pump 10 includes at least one gearbox 18 which connects the actuation member 17a of the first shaft 15 to the actuation member 17b of the second shaft 16. In one embodiment, the gearbox 18 can effect a reduction and/or multiplication of the angular speed of rotation of the first shaft 15 and the second shaft 16.

[0051] The gearbox 18 may include a reduction unit. It is also possible that the gearbox 18 is integrated with the actuation members 17a, 17b, that is, the latter constitute at least part of the gearbox 18. In particular, if the actuation members 17a, 17b are gears, they can engage with other gears of the gearbox 18.

[0052] In one possible operating mode, the gearbox 18 functions to reduce the speed of rotation of the first shaft 15 with respect to that of the second shaft 16. Alternatively, the gearbox 18 can function to reduce the speed of rotation of the second shaft 16 with respect to that of the first shaft 15.

[0053] Referring to the Figures, the pump 10 includes a drive member in the form of a motor 19 connected to the gearbox 18, in use to cause both the first impeller 13 and the second impeller 14 rotate. Both the first stage 11 and the second stage 12 of the pump 10 are mounted in (or formed in) a single support body 20. The support body 20 is provided with at least two chambers, respectively a first chamber 24 and a second chamber 25, in which respectively the first impeller 13 and the second impeller 14 are contained.

[0054] The support body 20 defines a suction (inlet) channel 21 and a delivery (outlet) channel 22 through which the stream of fluid is respectively introduced into and discharged from the pump 10. The first chamber 24 is in hydraulic communication with the suction (inlet) channel 21, while the second chamber 25 is in hydraulic communication with the delivery (outlet) channel 22. The support body 20 also includes a connection channel 23 provided to connect the first stage 11 with the second stage 12 of the pump 10, that is, to place the first chamber 24 and the second chamber 25 in hydraulic communication.

[0055] During normal use, the feed fluid to the pump 10 is taken in through the suction channel 21, where it is subjected to a first energy increase in the first stage 11 whereupon the fluid is transferred to the second stage 12 via the connection channel 23. In the second stage 12, the fluid is subjected to a further energy increase and is then discharged from the pump 10 via the delivery channel 22.

[0056] The first chamber 24 and the second chamber 25 are suitable to contain the first stage 11 and the second stage 12 and are suitably sized, in terms of volume, to take into account the fact that the fluid which is being pumped cannot be compressed.

[0057] Referring to Figure 1, the first stage 11 may include a volute 26, which is a spiral chamber with an increasing section in the direction of motion of the fluid, interposed between the first chamber 24 and the connection channel 23, and which is configured to convert the kinetic energy possessed by the fluid into pressure energy.

[0058] According to the variant embodiment shown in Figure 2, which can possibly be combined with elements already described in Figure 1, the first stage 11 may include a diffuser 27 interposed between the first chamber 24 and the connection channel 23, and also configured to convert the kinetic energy possessed by the fluid into pressure energy. In other possible embodiments, the diffuser 27 may be provided with diffusion blades.

[0059] Referring to Figure 1, the second stage 12 may also include a volute 28, interposed between the second chamber 25 and the delivery (exit) channel 22.

[0060] According to the variant embodiment shown in Figure 2, which can possibly be combined with elements already described in Figure 1, the second stage 12 may also include a diffuser 39 interposed between the second chamber 25 and the delivery channel 22, and also configured to convert the kinetic energy possessed by the fluid into pressure energy. In other possible embodiments, the diffuser 39 may be provided with diffusion blades.

[0061] The support body 20 comprises a casing 29, made in a single body and provided with a first cavity 30 and a second cavity 31 that define respective portions of the first chamber 24 and

the second chamber 25. The first cavity 30 and second cavity 31 are accessible to the outside of the pump 10. During use, the first cavity 30 and second cavity 31 respectively house, at least in part, the first impeller 13 and the second impeller 14.

[0062] The embodiment shown in the Figures not only allows the pump 10 to be more compact, but also provides a standard size of casing for different flow capacity sizes of pump. Thus the standard casing 29 can be used to cover a wide range of fluid handling operations, and the pump itself can be adapted on each occasion by the use of suitable internal adapters, depending on the specific design specification requirements. On at least one of either the first cavity 30 or the second cavity 31, one or more adaptors 32 are mounted during use, (as provided for example for the second stage 12 in Figures 1, 2 and 3), to adapt the geometry of the first chamber 24 and/or the second chamber 25 to the type and size of impeller being adopted.

[0063] For example, an adaptor 32 is inserted in a housing seating 34, made in the casing 29. The left hand side surface of the adaptor 32 (as shown in the Figures) defines part of the internal shape of the second cavity 31. The adaptor 32 is generally annular in shape and includes a central opening which allows fluid delivered from the first stage to pass through to the impeller of the second stage. The adaptor 32 also has the function of supporting various other support elements 33 such as seals, journals, bushings and/or bearings, which are configured to support, and allow the rotation of, the second impeller 14.

[0064] In other embodiments, such an adaptor 32 can also be associated with the use and operation of the first chamber 24.

[0065] In other embodiments, the first cavity 30 and/or the second cavity 31 are respectively configured to support the first impeller 13 and/or the second impeller 14, and to directly contain these impellers at least partly inside them. The first cavity 30 and/or the second cavity 31 can be provided with respective housing seatings in which the support elements 33 for the impellers are mounted directly.

[0066] The support body 20 also includes one or more closing lids 35 to close the casing 29, configured respectively to close the first impeller 13 and/or the second impeller 14 in the first cavity 30 and the second cavity 31, in this way so defining the first chamber 24 and the second chamber 25. According to the embodiment shown in Figure 1, the support body 20 includes two closing lids or back liners 35, one associated with the first stage 11 and the other associated with the second stage 12. This embodiment simplifies the assembly operations of the first impeller 13 and the second impeller 14.

[0067] In the alternative embodiment shown in Figure 2, the support body includes a single closing lid or back liner 35 configured to close both the first cavity 30 and the second cavity 31.

[0068] The closing lid or lids 35 (as shown in Figures 1 and 2) are provided with through holes 36 through which the first shaft 15 and the second shaft 16 are disposed through.

[0069] Support elements 37 can be inserted into each of the through holes 36, for example seals, journals, bushings, bearings or similar support components, configured to support the first shaft 15 and/or the second shaft 16 and to allow them to rotate around the respective axis of rotation X1 and respectively X2.

[0070] Furthermore, sealing elements 40 can be inserted into each of the through holes 36, to enable containment of the fluid being processed inside the pump 10.

[0071] Between the support body 20 and the gearbox 18, some rigid connection members 38 can be interposed, inserted between the closing lid 35 and the gearbox 18.

[0072] Referring to Figure 3, in this embodiment the adaptor 32 is dimensioned to adapt the internal dimensions of casing 29 to suit the diffuser 39 and the impeller 14. In this embodiment diffuser 39 is split into two components which sit on either side of the impeller 14.

[0073] As best seen in Figure 3, the gearbox 18 includes a large gear 17b mounted on the shaft 15 of the first stage of the pump and a smaller gear 17a mounted on the shaft 16 of the second stage of the pump. The ratio of the gears 17a, 17b defines the ratio of the speeds of rotation of their respective shafts. The gears 17a, 17b are able to be removed from the shafts 15, 16 and replaced with gears of different sizes to provide for different ratios of the speeds of the two shafts, to suit particular desired pumping requirements.

[0074] It can be seen that embodiments of the pump have at least one of the following advantages:

- By the use of one or more adaptors, it is possible to use one size of pump body for configuring a pump so that it can be used with many different types and sizes of impeller to suit various duties, such as handling a variety of fluid types, over different ranges of flow rates and pressures. Thus, one pump body can cover specific applications in a wide functioning field. For example, one size of pump body can be used to achieve a flow range from 5 to 200 m³/hr and a head range from 150 m to 1800 m

- Use of a single size of pump body allows for a simplification of manufacturing operations, since there is no need to maintain multiple dedicated apparatus, such as casting molds, which would otherwise be needed to manufacture different pump body sizes for use in different applications. This in turn can reduce costs by reducing manufacturing inventory and streamlining the manufacturing process. For example, by having an unchanging standard size of pump casing, closing lid, shaft, gear frame and bearing, the manufacturer only needs to produce a stock of impellers, gears, adaptors and diffusers (flow parts) in order to produce a new pump according to a customer order. The standard size parts can be manufactured in bulk, thereby saving costs, and held in stock. Because the whole pump does not need to be made at one time, and only the flow parts are made in response to a customer order, this can achieve a substantial drop in pump delivery time - for example 10 weeks rather than the more usual 30-60 weeks, therefore allowing potential access to more end user customers who operate in rapid demand markets.

[0075] In the foregoing description of certain embodiments, specific terminology has been resorted to for the sake of clarity. However, the disclosure is not intended to be limited to the specific terms so selected, and it is to be understood that each specific term includes other technical equivalents which operate in a similar manner to accomplish a similar technical purpose. Terms such as “left” and “right”, “front” and “rear”, “above” and “below” and the like are used as words of convenience to provide reference points and are not to be construed as limiting terms.

[0076] In this specification, the word “comprising” is to be understood in its “open” sense, that is, in the sense of “including”, and thus not limited to its “closed” sense, that is the sense of “consisting only of”. A corresponding meaning is to be attributed to the corresponding words “comprise”, “comprised” and “comprises” where they appear.

[0077] In addition, the foregoing describes only some embodiments of the inventions, and alterations, modifications, additions and/or changes can be made thereto without departing from the scope and spirit of the disclosed embodiments, the embodiments being illustrative and not restrictive.

[0078] Furthermore, inventions have been described in connection with what are presently considered to be the most practical and preferred embodiments, it is to be understood that the invention is not to be limited to the disclosed embodiments, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the inventions. Also, the various embodiments described above may be implemented in conjunction with other embodiments, e.g., aspects of one embodiment may be combined with aspects of another embodiment to realize yet other embodiments. Further, each independent feature or component of any given assembly may constitute an additional embodiment.

WHAT IS CLAIMED IS:

1. A two-stage centrifugal pump comprising:
 - a first stage provided with a first impeller; and
 - a second stage provided with a second impeller and hydraulically connected to the first stage;
 - the first impeller being mounted on a first shaft and the second impeller being mounted on a second shaft distinct from said first shaft;wherein the first stage and the second stage are located in a support body, the support body being provided with a first chamber and a second chamber in which the respective first impeller and the second impeller are contained; and
wherein the support body comprises a single casing provided with a first cavity and a second cavity that each define respective portions of said first chamber and said second chamber; and
wherein in at least one of either the first cavity or the second cavity, one or more adaptors are mounted, in use to adapt the geometry of the first chamber and/or the second chamber to the type and size of impeller adopted.
2. A pump according to claim 1, wherein said first shaft and said second shaft have respective axes of rotation arranged parallel to each other.
3. A pump according to either of claim 1 or claim 2, wherein each of the first shaft and the second shaft is connected to a respective actuation member selected from between a motor, at least one gear or a combination thereof.

4. A pump according to claim 3 comprising a gearbox that connects the actuation member of the first shaft to the actuation member of the second shaft.
5. A pump according to claim 4 comprising a drive member connected to the gearbox to make both said first impeller and said second impeller rotate.
6. A pump according to either of claims 4 or 5 wherein the gearbox obtains a reduction and/or multiplication of the angular speed of said first shaft with respect to that of said second shaft.
7. A pump according to any one of claims 4 to 6 wherein the gearbox comprises a reduction unit.
8. A pump according to any one of the preceding claims, wherein one or more of the adaptors also includes a support element to support and allow the rotation of either the first or second impellers.
9. A pump according to any one of the preceding claims, wherein the support body defines a suction channel and a delivery channel through which the stream of fluid is respectively introduced into, and discharged from, the pump.
10. A pump according to any one of the preceding claims, wherein the support body includes a connection channel which hydraulically connects the second stage to the first stage.
11. A pump system including:
 - a pump according to any one of the preceding claims, and

- a range of adaptors to adapt the geometry of the first chamber and/or the second chamber to suit the type and size of a range of impellers and/or diffusers.
12. A pump system according to claim 11, further including a range of gears which can be selected to define the angular speed of said first shaft with respect to that of said second shaft.
13. A method of configuring a centrifugal pump, the pump comprising:
- a first stage provided with a first impeller; and
 - a second stage provided with a second impeller and hydraulically connected to the first stage;
 - the first impeller being mounted on a first shaft and the second impeller being mounted on a second shaft distinct from said first shaft;
- wherein the first stage and the second stage are located in a support body, the support body being provided with a first chamber and a second chamber in which the respective first impeller and the second impeller are contained; and
- wherein the support body comprises a single casing provided with a first cavity and a second cavity that each define respective portions of said first chamber and said second chamber; and
- wherein the method includes the steps of:
- adopting an impeller of a particular type or size for use in each of the first and second chamber; and

- selecting one or more adaptors for mounting in at least one of either the first cavity or the second cavity, in use to adapt the geometry of the first chamber and/or the second chamber to the type and size of impeller adopted.

14. A method according to claim 13, the method further including the step selecting at least one gear from a range of gears to define the angular speed of said first shaft with respect to that of said second shaft.