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(71) Applicant: **SULZER PUMPEN AG**
8401 Winterthur (CH)

(72) Inventor: **Puittinen, Reijo**
49490 Neuvoton (FI)

(74) Representative: **Intellectual Property Services GmbH**
Langfeldstrasse 88
8500 Frauenfeld (CH)

(54) **A centrifugal pump and a method of pumping a medium**

(57) The present invention relates to a centrifugal pump and a method of pumping a medium. The present invention relates especially to a centrifugal pump having a novel impeller - volute casing construction where the working vanes (136) of the impeller (130) extend into the cavity (116) formed in the volute casing (110). The centrifugal pump and the method of the present invention are especially suitable for pumping fibrous paper or board making suspensions.

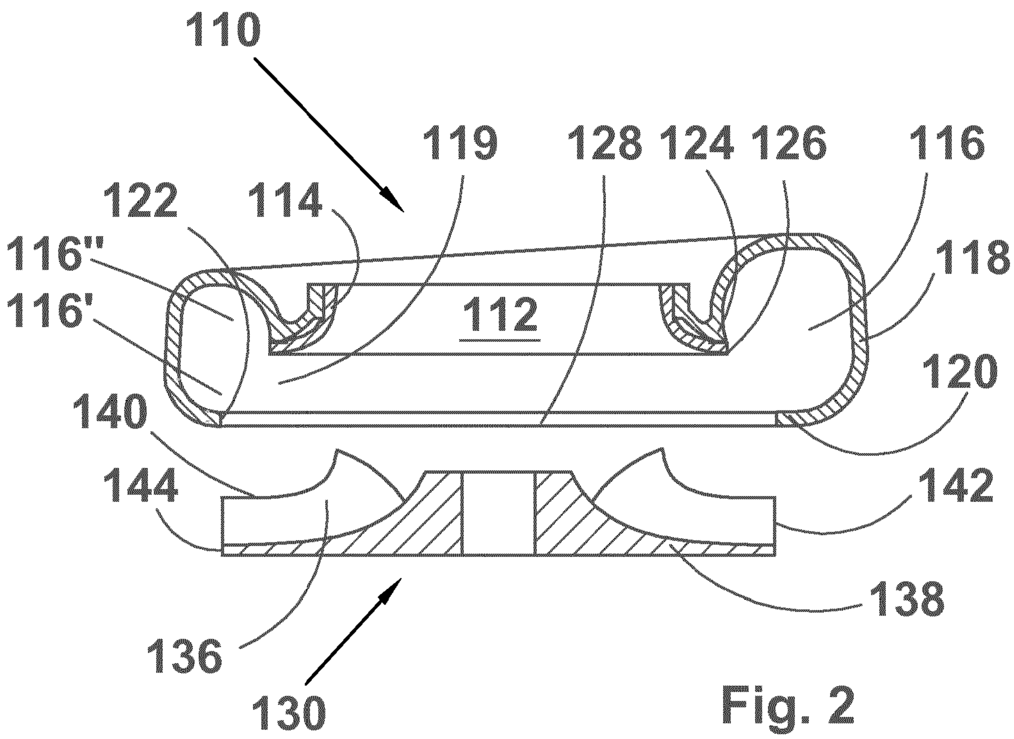

Fig. 2

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Description

Technical field

[0001] The present invention relates to a centrifugal pump and a method of pumping a medium. The present invention relates especially to a centrifugal pump having a novel impeller - volute casing construction. The centrifugal pump and the method of the present invention are especially suitable for pumping fibrous paper or board making suspensions.

Background art

[0002] The main components having an influence on the pumping characteristics of a centrifugal pump are the volute casing or volute and the impeller. The impeller is formed of a hub and working vanes attached to the hub. The hub is provided with a central hole for fastening the impeller to the shaft of the pump. The above described impeller, i.e. the one having merely a hub and working vanes, is called an open impeller. If the hub is extended radially outwardly by means of a so called rear plate to which the working vanes are arranged at their rear edges, the impeller is called a semi-open impeller, i.e. the front edges of the working vanes being free or open. If the front edges of the working vanes are fastened to a plate, so called front plate, which extends to the entire radial dimension of the working vanes, the impeller is called a closed impeller. If desired, an impeller having a front plate, which does not extend to the outer edges of the working vanes but leave the front edges of the working vanes open near the perimeter of the impeller, is called a partially closed impeller.

[0003] The volute casing comprises normally a front wall of the pump starting from the suction inlet and continuing radially outwardly, substantially following the shape of the front edges of the working vanes of the impeller, to form a cavity to which the impeller pumps the medium to be pumped. Normally the cross sectional area of the cavity increases in the direction of rotation of the impeller up to the discharge outlet opening to which is normally arranged a tangential pressure outlet duct for discharging the medium further in the process. The outlet duct is usually situated radially outside of the impeller for minimizing pressure losses. The point where the discharge flow separates from the flow continuing its circulation in the volute is called a cutwater. The cavity has a wall the cross section of which is in a radial plane annular, sometimes almost circular, except for the opening at its inner section where the impeller feeds the pumped medium into the cavity. The opening is, naturally, located to the radially innermost part of the volute.

[0004] There are two basic types of volute casings, namely single suction or double suction types. When a centrifugal pump is of single suction type, it draws liquid from one axial side of the pump and pumps it radially out of the pump. In double suction pumps the pump draws the liquid from both opposite axial sides of the pump, and pumps the liquid radially out of the pump. The same division of types may be applied to impellers; too, i.e. the impellers are also single suction or double suction types. And the double suction impellers may also be open, semi-open or closed like the single suction impellers.

[0005] The dimensioning of the impeller in relation to the cavity of the volute casing is in prior art centrifugal pumps normally such that the impeller and especially the working vanes thereof, extend in radial direction at most into the above mentioned opening, but not any further. The described structure is supposed to give the pump the best available efficiency and head.

[0006] However, it has been known for decades, almost a century that a centrifugal pump causes pressure pulsation in the liquid it pumps. Such pressure pulses are created each time a working vane passes the cutwater. In most pump installations the pulsation is not even recognized at all, or not considered a problem. But in some cases, like for instance in feeding paper making stock to a headbox of a paper making machine, the pulsation is a true problem, and both the headbox feed pump and the headbox itself have been provided with means for fighting the pulsation.

[0007] Another problem found in prior art centrifugal pumps is, when pumping fibrous suspensions, the tendency of the fibers to form flocs, i.e. small groups of fibers attached to each other, in the suspension. A further problem may be experienced as difficulties in pumping if the turbulence level in the spiral is not high enough. If such a pump is feeding paper making stock to the headbox and the flocs end up onto the wire of the paper machine, the flocs reduce the quality of the end product, and at their worst create holes in the web.

Brief summary of the Invention

[0008] Thus an object of the present invention is to develop a new type of a centrifugal pump and a method of pumping a medium capable of solving at least one of the above discussed problems.

[0009] Another object of the present invention is to develop such a novel centrifugal pump and a method of pumping a medium that reduces the pulsation level compared to the prior art centrifugal pumps.

[0010] A further object of the present invention is to develop such a novel centrifugal pump and a method of pumping a medium that reduces the tendency of floc formation.

[0011] At least one of the objects of the present invention is fulfilled by a centrifugal pump for pumping a medium, the centrifugal pump having a shaft, an impeller on the shaft and a volute casing housing the impeller; the impeller having working vanes each having an outer edge and a front edge; the volute casing having a circumferentially extending cavity having a cross section formed by a wall; the wall having a rear wall section with a radially inner edge, an inner wall section with an inner edge and an opening for allowing medium pumped by the impeller to enter the cavity in radial direction directly from the impeller; the volute casing further having a cutwater radially outside of the impeller, the cutwater separating a pressure outlet duct from the cavity, the pressure outlet duct being located radially outside of the impeller wherein the cross section of the cavity is oval such that the cavity has wherein the oval cavity has a first axial end and a second axial end, the opening being located at the inner circumference of the first axial end, the working vanes of the impeller extending into the first axial end of the oval cavity via the opening such that the front edges of the working vanes are facing the second axial end of the oval cavity and that the pressure outlet duct extends to the entire axial width of the volute casing.

[0012] At least one of the objects of the present invention is fulfilled by a method of pumping a medium with a centrifugal pump of claim 1, wherein

- medium is pumped by means of the impeller radially outwardly and tangentially to a first axial end of an oval cavity within the volute casing,
- medium is guided spirally along the wall of the oval cavity up to a second axial end of the cavity and from there back to the first axial end of the oval cavity,
- shear forces are subjected to medium by means of the front edges of the working vanes of the impeller, the front edges extending into the oval cavity and increasing the velocity and momentum of medium, and
- a part of the spirally advancing medium is guided from the entire axial width of the oval cavity by means of a cutwater radially outwardly to the outlet duct of the centrifugal pump.

[0013] Other characterizing features of the centrifugal pump and the method of the present invention become evident in the accompanying dependent claims.

[0014] The centrifugal pump and the method of the present invention bring about several advantages in comparison to prior art centrifugal pumps. At least the following advantages may be listed:

- Low level of pulsation
- Reduced demand for space
- Smaller forces
- Possibility to mix chemicals in the cavity of the volute casing with the liquid to be pumped
- Preventing the formation of flocs in the volute in the medium to be pumped, as strong shear forces are created in the volute.

Brief Description of Drawing

[0015] The centrifugal pump and the method of the present invention are described more in detail below, with reference to the accompanying drawings, in which

Fig. 1 illustrates schematically an axial cross sectional view of a prior art single suction centrifugal pump,

Fig. 2 illustrates schematically an axial cross sectional view of a single suction centrifugal pump in accordance with a first preferred embodiment of the present invention,

Fig. 3 illustrates a more detailed partial axial cross sectional view of a prior art centrifugal pump,

Fig. 4 illustrates a more detailed partial axial cross sectional view of a centrifugal pump in accordance with a first preferred embodiment of the present invention,

Fig. 5 illustrates schematically an axial cross sectional view of a double suction centrifugal pump in accordance with a second preferred embodiment of the present invention,

Fig. 6 illustrates a radial cross section of a centrifugal pump in accordance with a first preferred embodiment of the present invention, and

Fig. 7 illustrates schematically an axial cross sectional view of a single suction centrifugal pump in accordance with a third preferred embodiment of the present invention.

Detailed Description of Drawings

[0016] Figure 1 is a general cross sectional illustration of a prior art centrifugal pump showing only the volute casing 10 and the impeller 30. The components, i.e. the volute casing 10 and the impeller 30 have been shifted apart in axial direction such that their structure would be easier to comprehend. The volute casing 10 comprises an inlet or suction opening 12 the inner surface of which is formed of a wear plate 14. The wear plate 14 is a replaceable and axially adjustable annular plate that extends in the direction of the flow from the inlet opening towards a pressure outlet duct (not shown) in the outer circumference of the volute casing 10. The purpose of the wear plate 14 is to protect the volute casing 10 itself when pumping such medium that tends to wear the components used for pumping. Another purpose of the wear plate 14 is to be able to adjust the running clearance of the impeller. In other words, when the wear plate has worn to a certain extent, it may be moved closer to the impeller so that the running clearance of the impeller may be brought back to correspond to that of a new pump. However, the wear plate 14 is not a necessary component of the volute casing 10, but the casing surface itself may be open to the medium to be pumped (see for instance Fig. 5). The wear plate is normally used with open or semi-open impellers as a closed impeller itself (see for instance Fig. 7) has a front plate preventing the wear of the volute casing.

[0017] The volute casing 10 comprises further a cavity 16 into which the impeller pumps the medium via opening 19 and in which the medium to be pumped circulates (in the circumferential direction) before being discharged from the pump via the discharge or pressure outlet (not shown). The cavity 16 of the volute casing 10 is substantially circular of its cross section and traditionally located immediately (radially) outside of the impeller 30 such that the medium may be pumped by the impeller via the opening 19 radially outwardly into the cavity without any additional restrictions. The same positioning applies to the pressure outlet duct of the volute casing, too, i.e. it extends to the entire axial width of the volute casing and is most often positioned to depart tangentially from the cavity 16, whereby its longitudinal axis is usually located in the same radial plane with the circumferential axis of the cavity 16. Additionally, the opening 19 is arranged in the centre region of the inner circumference of the cavity 16, whereby the cavity extends substantially symmetrically to both sides of the radial centreline plane of the opening 19. The cavity 16 has an annular wall 18, starting from a rear wall section 20 or rather from an inner edge 22 thereof and terminating to an inner wall section 24 with an edge 26. The edges 22 and 26 leave the opening 19 therebetween via which the impeller pumps the medium into the cavity 16. The edge 22 of the rear wall section 20 of the volute casing 10 defines a central rear opening 28 via which the impeller may be brought into the volute casing 10. In other words, without specific arrangements the diameter of the rear opening 28 equals to at least the diameter of the impeller 30, or, in fact, is slightly larger. The volute casing may, however, be formed of several parts. The front wall including the inlet or suction opening may be a part separate to the part forming the cavity. Also it is possible to form the cavity, or in fact the volute casing, of two separate parts. In such a case the volute casing is divided into two parts, i.e. either in radial direction or in axial direction. In both latter cases, the diameter of the rear opening 28 may be smaller than that of the impeller 30.

[0018] The impeller 30 illustrated in Figure 1 is a so called semi-open impeller, i.e. having a hub 32 with a central opening/hole 34 for the shaft, working vanes 36 and a rear plate 38. The working vanes 36 have a front edge 40, which is, over its entire length, facing the volute casing 10 and arranged, in an assembled centrifugal pump, at a certain distance from the volute casing 10 or (if used) from its wear plate 14, and a radially outer edge 42, which faces the opening 19 to the cavity 16 of the volute casing 10. The rear plate 38 of the impeller 30 has an outer edge 44 which is arranged in close proximity of the inner edge 22 of the rear wall section 20 of the cavity 16. However, in case the impeller has so called rear vanes, i.e. vanes at the rear side of its rear plate 38, the outer edge 44 of the rear plate 38 leaves a gap in both axial and radial direction between itself and the inner edge 22 of the rear wall section 20 of the cavity 16 for the medium pumped by the rear vanes to enter the cavity 16.

[0019] Figure 2 is a schematical axial cross sectional illustration of a single suction centrifugal pump in accordance with a preferred embodiment of the present invention. To show the actual differences to the prior art pump the impeller 130 of the embodiment of Figure 2 is equal to the impeller 30 of Figure 1, i.e. it is a semi-open impeller, and has the same elements, whereby the same reference numerals are used except that each of them is preceded by '1'. It is the volute that has been re-designed in the present invention. The volute casing 110 is basically similar to the one shown in Figure 1, in other words, its cross sectional area grows circumferentially, i.e. in the direction of the rotation of the impeller, and it is located immediately (radially) outside of the impeller 130 such that the medium may enter the cavity 116 via opening 119 without any additional restrictions. The same approach applies to the pressure outlet duct of the volute casing 110, too, i.e. it extend to the entire axial width of the volute casing 110 and is positioned to depart tangentially from the cavity 116, whereby it is located at the same radial plane with the impeller 130 and the cavity 116. However, the volute casing 110 has a few interesting differences.

[0020] Firstly, the cross section of the cavity 116, is not any more circular or round as in prior art pumps, but it is oval. In other words, the cross section of the cavity 116 or the volute casing is compressed or reduced in radial direction whereby it has expanded or increased in axial direction. Thus, in this connection the word "oval" includes both elliptical and such substantially quadrangular shapes that have well-rounded corners for ensuring easy spiral circulation of the medium in the cavity 116. An essential feature of the volute casing 110 or the cavity 116 of the present invention is that the opening 119 introducing the medium from the impeller to the cavity 116 is not located centrally at the inner circumference of the cavity 116, but at an axial end, or a first axial end, of the cavity. This means that the cavity 116 is located asymmetrically in relation to the radial centreline plane of the opening 119. The above described construction of the volute casing ensures an efficient recirculation of the medium back to the impeller.

[0021] Secondly, the overall diameter of the volute casing 110 is smaller than that of the volute casing 10 in the prior art Figure 1. The main reason for this structural feature is that the cross sectional area of the oval volute casing increases mostly in axial direction from the rear wall section towards the side of the inlet of the pump, i. e. asymmetrically in relation to the opening 119 arranged for the impeller and/or the medium to be pumped in the volute casing. In conventional pumps the cross sectional area of the volute casing grows equally in both radial and axial directions, i.e. symmetrically in relation to the opening leading from the impeller to the volute casing.

[0022] Thirdly, the rear wall section 120 of the cavity 116 of the volute casing 110 does not any more extend to the entire radial width of the cavity 116 as it did in the prior art volute casing 10 of Figure 1, but the impeller rear plate 138 extends radially outwardly such that it, in a way, forms a part of the rear wall of the cavity 116.

[0023] The reason for the first three differences is the fact that, in accordance with the first preferred embodiment of the present invention, the working vanes 136 of the impeller 130 are made to extend in radial direction into the cavity 116 via the opening 119. In this embodiment of the present invention the rear plate 138 of the impeller 130, i.e. its radially outer edge 144 extends in radial direction to the same diameter as the working vanes 136. However, it has to be understood that such is not always necessary. If a gap is formed between the inner edge 122 of the rear wall section 120 of the volute casing 110 and the outer edge 144 of the impeller 130 the pump rear wall (not shown) may be made to fill the gap. In any case it is advantageous that the opening 128 in the rear of the volute casing 110 has at least the same diameter (in practice slightly larger) than that of the impeller 130 at its largest, i.e. that of the outer edges 142 of the working vanes 136 or that of the outer edge 144 of the rear plate 138, whichever extends radially farther from the axis of the impeller 130. In an assembled centrifugal pump in accordance with a preferred embodiment of the present invention the working vanes 136 of the impeller 130 extend radially farther away from the axis than the edge 126 of the inner wall section 124 of the annular wall 118 of the cavity 116 of the volute casing 110. This means, in practice that the front edges 140 of the working vanes are, for a certain part of their length, open to the cavity 116 contrary to prior art pumps. Advantageously, but not necessarily, the diameter of the edge 126 of the inner wall section 124 is 80 - 90 % of the diameter of the impeller, i.e. that of the outer edges 142 of the working vanes, to be more specific. However, it has to be understood that the lower is the above defined percentage, the stronger is the spiral movement in the cavity 116 (meaning more efficient turbulence and mixing) and the higher is its influence on the pumping efficiency. As shown in Figure 2 the edge 126 of the inner wall section 124 may be located not only as an integral part of the volute casing but also as the outer edge of the wear plate 114. Thus the outer rim of the wear plate 114 may be considered to form a part of the inner wall section 124. In accordance with another preferred embodiment of the present invention the edge 126 of the annular wall 118 of the cavity 116 of the volute casing 110 extends to the side plate or wear plate 114, and, in fact, is a part thereof. And further, in accordance with a further preferred embodiment of the present invention, the edge 126 of the annular wall 118, which may be a part of the side plate 114 or integrated to the volute casing 110, may form a kind of a deflector directing the recirculating flow more or less in outward direction and not only axially towards the impeller 130. When the edge 126 forms a deflector it means structurally that the edge 126 extends deeper into the cavity 116 or radially more outwardly than the radially innermost surface of the inner wall section 124.

[0024] And finally, the fourth difference is the reduced radial distance between the inlet opening 112 and the cavity 116 in the volute casing 110, which is due to the reduced overall diameter of the volute casing 110 and the existence of the same inlet opening 112 diameter. Thereby the distance is so small that the wear plate 114 may be easily extended to cover the entire distance. However, the wear plate may also be made shorter, i.e. in line with the teachings of Figure 1, for instance, or the wear plate may be entirely left out (see for instance Fig. 5). This depends mainly on the intended use of the pump.

[0025] Figures 3 and 4 illustrate in more detail the differences between the prior art centrifugal pump (Figure 3) and the centrifugal pump of the present invention (Figure 4). The Figures show clearly how the impeller vanes 136 of the impeller 130 of the invention, i.e. those of Figure 4 extend in radial direction deep in the cavity 116, whereas vanes 36 of the prior art pump do not extend in the cavity 16 at all, but just feed the pumped medium into the cavity 16. In other words, the outer edges 142 of the working vanes 136 of the present invention are located radially farther from the axis of the pump than the inner edge 126 of the inner wall section 124 of the wall 118 of the cavity 116. This kind of positioning of the radially outer edge 142 of the working vanes 136 brings the front edge 140 of the working vanes 136 in the cavity 116, too, i.e. the front edges 140 are, for a certain part of their length, open to cavity 116. In the prior art centrifugal pump the front edge of the working vanes 36 has followed the volute casing, or the wear plate 14, or both with a small running clearance up to the inner edge 26 of the inner wall section 24, but has not been extended any further. In the pump of the present invention the front edge 140 of the working vanes 136 follows the inner surface of the volute casing, or the wear plate 114, or both with a small running clearance up to the inner edge 126 of the inner wall section 124, and extends radially outwardly therefrom into the cavity 116. This is especially important in view of the operation of the pump of the present invention, as explained in more detail in the following.

[0026] The impeller of the centrifugal pump feeds the pumped medium radially outwardly in the volute casing, whereby the medium starts to follow the inside surface of the wall 18/118 of the volute casing 10/110. In other words, the pumped medium advances along a spiral path in the cavity 16/116 of the volute casing up to the cutwater (shown in Figure 6), which is located just radially outside of the impeller in the opening 19/119. At the cutwater area the both circumferentially and spirally flowing medium is divided such that a part of the medium continues to follow the spiral path in the cavity 16/116 and another part is discharged from the pump via the pressure outlet. Thus that is basically what happens both in the prior art pump and in the pump of the present invention.

[0027] However, there are clear differences in the operation of the pump of the invention when compared to a prior art pump. Firstly, as the cavity 116 is asymmetrically positioned in relation to the working vanes 136, the medium entering substantially tangentially to a first axial end 116' of the oval cavity 116 is efficiently guided to a spiral flow along the wall of the cavity to the second axial end 116" of the cavity and from there back to the first axial end 116' of the cavity into communication with the working vanes. When compared to the prior art pump it is easy to understand that the spiral flow is much more efficient in the pump of the present invention, as in prior art pumps the flow enters the cavity along the diameter thereof and not tangentially whereby an efficient spiral flow cannot be formed as two counter rotating flows are formed in the spiral. Secondly, as the working vanes 136 of the present invention extend into the cavity 116, they increase the rotational velocity of the spiral flow in the cavity 116, as a part of the medium rotating already in the cavity reaches the vanes, the front edges 140 of the working vanes 136 to be more specific, i.e. enters the spaces between the vanes and, thus, gets into physical contact with the vanes 136, whereby the vanes 136 feed energy directly to the already pumped medium and thus increases the momentum of the medium. And thirdly, the working vanes 136, when rotating inside the cavity 116, subject the spirally rotating medium flow to strong shear forces, especially by means of their front edges 140.

[0028] The shear forces may be utilized in several different ways. An option is to introduce one or several chemicals (as discussed later in connection with Figure 7) into the cavity 116, i.e. to the spiral flow advancing towards the working vane region, where the strong shear force field is able to mix the chemical/s efficiently with the pumped medium. The shear forces may also be utilized when pumping medium that includes flocs or tends to allow floc formation, the medium being paper making stock, for instance. In such a case, the flocs are loose groups of fibers that, if entering the wire section of the paper making machine, reduce the quality of the end product. Now that the medium, for instance paper making stock, is subjected to strong shear forces by the front edges 140 of the working vanes 136 the shear forces break the already formed flocs and prevents the formation of any new flocs.

[0029] The above described impeller - volute casing configuration improves also the struggle against the pulsation. It has been understood for a long time that the pulsation is for the most part caused by, on the one hand, the pressure difference over the working vane, and, on the other hand, the abrupt change in velocity caused by a working vane passing the blunt cutwater. In the impeller - volute casing configuration of the present invention the pressure difference over the working vane is considerably reduced due to the more efficient spiral or recirculating flow at the outer edge area of the working vanes of the impeller. What, in fact, happens now that the impeller is at one side thereof open to the spiral flow is that the spirally advancing or recirculating flow is able to enter the space between the working vanes, i.e. the areas of reduced pressure at the trailing surfaces of the working vanes are, in a way, filled with the spirally advancing medium balancing the pressure difference significantly. A feature aiding in receiving the flow between the vanes is an advantageous, but not necessary, inclining of the working vanes towards the flow. In other words, the working vanes are not necessarily at right angles to the impeller rear plate but inclined against the direction of rotation, i.e. the leading angle between each working vane and the rear plate is less than 90 degrees.

[0030] Additionally, now that the relative movement of the vane in front of the cutwater takes place in a significantly larger angle in relation to the direction of the main liquid flow than in conventional pumps (for instance 54 degrees vs. 30 degrees) the time, the vane needs for passing the cutwater area, is much longer. This will have positive impact to pulsation, as it reduces the pressure peaks in the flow domain. In other words, the pressure peaks are the lower the longer the pulse takes, i.e. the longer the working vane is in communication with the cutwater.

[0031] Figure 6 may be used to describe the above in more detail. Circle 126 may be considered to correspond to the outer circumference of the working vanes of a prior art pump, which, as has been discussed in connection with Figure 1, do not extend into the cavity of the volute casing at all. In such a case the length of a pressure pulse the working vane creates is considered to be the angular dimension it takes for the working vane to pass the cutwater. In conventional pumps the pulse length is intentionally increased for reducing the pulse strength by inclining the working vanes in relation to the direction of the cutwater such that, firstly, a leading edge (normally the front edge, whereby the leading angle of the working vane is sharp) of the working vane passes the cutwater, and, secondly, for a while later, the trailing edge, i.e. the edge attached to the rear plate of the impeller, of the vane passes the cutwater. Thus, depending on the inclination of the working vane, the pulse length varies between 0 (used in cases when the pulsation is not taken into consideration at all) and about 30 degrees.

[0032] When using the impeller -volute casing combination of the present invention the pulse length is much longer as the actual cutwater may be considered to be a U-shaped element, i.e. formed of the cutwater 150 of Figure 6 and the edge 126 of the inner wall section of the oval cavity 116. The pulse is considered to start when the outer edge of the working vane 136 starts to descend in relation to the edge 126 of the inner wall section. This is shown in Figure 6 by line L, which meets the circle 142/144 representing the outer circumference of the working vanes 136 at such a point that the leading surface of the working vane 136 meets the point where the extension of the wall (lower one in Figure 6) of the outlet duct 152 forms a tangent to the circle 126, i.e. to the edge 126 of the inner wall section of the oval cavity 116. Thus the pulse length is shown in Figure 6 by angle β, i.e. from the cutwater 150 to line L.

[0033] Also, as may be seen from Figures 1 and 2, as well as from Figures 3 and 4, the diameter of the pump of the present invention has a smaller diameter than the prior art pump. In practice the diameter of an actual centrifugal pump utilizing the present invention may be reduced by tens of percents. This means in practice that pumps having a higher output may be positioned in the same space with conventional pumps having a lower output. Another measure saving space may be taken by increasing the opening angle of the pressure outlet duct, as the spirally advancing flow remains longer on the wall of the cone (shape of the internal surface of the pressure outlet duct) due to the stronger spiral flow maintaining stable outlet duct flow and a high outlet velocity better. By increasing the opening angle of the conical diffuser, the length of the pressure outlet duct may be shortened (this feature is discussed in more detail in connection with Figure 6) whereby the pump occupies a smaller place. All these reductions in the pump dimensions mean, not only savings in space, but also savings in manufacturing costs.

[0034] As to other effects the impeller - volute casing configuration of the present invention brings about the following may be mentioned. Firstly, it is evident that the radial forces of the pump are somewhat reduced, which is mainly due to the more uniform spiral flow in the cavity of the volute casing. Secondly, it could be argued that keeping the front edges 140 of the working vanes open in the cavity 116, i.e. without a front plate of a closed impeller the head will be reduced, but the performed tests have shown that the reduction is relatively small.

[0035] Figure 5 is a schematical axial cross sectional illustration of a double suction centrifugal pump in accordance with a preferred embodiment of the present invention. Here the same structural features as discussed in connection with the embodiments of Figures 2 and 4 have been taken into use in a double suction pump. The numbering of the components follows the earlier Figures with the exception that now reference numerals of Figure 1 are preceded by '2'. In other words, the outer edges 242 of the working vanes 236 of the impeller 230 extend clearly inside the cavities 216 of the volute casing 210. Here, also the option of having no wear plate has been shown. In other words, the medium to be pumped advances from the inlets 212 to the cavities 216 along the surface of the volute casing 210, and the front edges of the working vanes 236 follow the inner surface of the volute casing 210 at a small running clearance.

[0036] Figure 6 is a schematical radial cross sectional illustration of a centrifugal pump in accordance with a preferred embodiment of the present invention. The cross section may be considered to relate to both embodiments discussed above, i.e. to both single suction pumps and double suction pumps. However, the reference numerals refer to the components introduced in connection with Figures 2 and 4. Figure 6 also shows the cutwater 150, which is located radially outside of the impeller 130 and divides the medium flow recirculating or actually spirally advancing in the cavity 116 to a partial flow being discharged from the pump via pressure outlet duct 152 and another partial flow that continues to circulate and recirculate in the cavity 116. Figure 6 also shows the working vanes 136 of the impeller 130, the outer edges 142 of the working vanes, or the outer edge 144 of the rear plate 138, when they are located on the same diameter as well as the inner edge 126 of the annular wall 118 of the cavity 116 of the volute casing 110. Figure 6 additionally shows the opening angle α of the pressure outlet duct 152. The cross section of the pressure outlet duct 152 is, at its left hand end, circular, whereby the overall shape of the outlet duct transforms from the oval cross section of the volute casing to circular shape. The opening angle α of the pressure outlet duct is in traditional centrifugal pumps in a radial plane at most about 6 degrees. By means of the novel design of the impeller - volute combination the opening angle α may be increased to about 9 to 11 degrees without causing flow separation in the diffuser (influencing stability of the pumping). This means, in practice, that the length of the pressure outlet duct may be reduced significantly. In theory, if we assume that the length of the pressure outlet duct measured from the apex of the outlet duct is one meter when the opening angle is 6 degrees the length required with an opening angle of 11 degrees is only about 55 cm, i.e. the reduction here is 45%. The corresponding reduction is, in practice, in the least tens of percents. The reason for the possibility of reducing the length of the pressure outlet duct is the fact that now that the flow recirculates very powerfully in the volute along a spiral path, the same recirculation continues also in the pressure outlet duct keeping flow pattern stable. In traditional pumps the spiral flow or recirculation in the volute is significantly weaker, whereby also the spiral flow in the pressure outlet duct is weaker. The weakness of the spiral flow is easy to understand when looking at the shape of the cross section of the volute casings of Figures 1 and 3. In other words, now that the cross section is substantially round and the medium enters the volute casing in radial direction a single spirally recirculating flow in the casing cannot be formed but most probably two counter rotating vortices are formed in the casing. Such vortices dampen each other relatively quickly whereby the flow does not easily follow the surface of the outlet duct, but the opening angle of the outlet duct has to be matched with the weak circulation.

[0037] Figure 7 illustrates schematically an axial cross sectional view of a single suction centrifugal pump in accordance with a third preferred embodiment of the present invention. As shown in the Figure the impeller

330 of the single suction centrifugal pump is a partially closed impeller, i.e. provided with a front plate 350 so that for the majority of their length the working vanes 336 are located between the front plate 350 and the rear plate 338 of the impeller 330. Now the inner edge 326 of the inner wall section 324 of the annular wall 318 of the cavity 316 of the volute casing 310 is, in fact, an extension of the inner wall section 324 and is located in the front plate 350 of the impeller 330 such that the working vanes 336 extend radially outwardly from the inner edge 326. The front plate 350, which is sometimes called a side plate, is arranged at a distance from the volute such that an annular chamber 352 is left therebetween. The annular chamber 352 is, in an additional preferred embodiment of the present invention, provided with an inlet conduit 354 for introducing chemical to the annular chamber 352. The chemicals that may be added by using the pump of the present invention include, but are not by any means limited to, chlorine dioxide (ClO_2), hydrogen peroxide (H_2O_2), sodium hydroxide (NaOH), sulfuric acid H_2SO_4, calcium hydroxide ($Ca(OH)_2$), Polyacrylamide (PAM), ferric sulfate ($Fe_2(SO_4)_3$), oxygen O_2, etc. Thus it is obvious that by means of the present invention both liquid and gaseous chemicals may be added to the medium to be pumped. At the radially outer circumference of the annular chamber 352 there is a circumferential gap 356, or, optionally, substantial number of radial grooves, between the front plate 350 and the volute for the chemical to be introduced to the cavity 316. When the chemical is introduced via the gap 356 into the cavity 316, the chemical enters the spirally recirculating flow to such a location that the flow immediately after receiving the chemical enters the area of the front edges 340 of the working vanes 336 that subject the flow to a strong turbulence, which ensures even and quick mixing of the chemical among the liquid to be pumped.

[0038] In view of the above description it should be understood that the present invention may be applied in connection with both open, closed, partially closed and semi-open impellers as well as with single or double suction centrifugal pumps. Also, it should be understood that the introduction of chemical/s to the volute discussed in more detail in connection with Figure 7 may be applied in connection with any other embodiment of the invention, and that the partially closed impeller structure discussed in Figure 7 may, naturally, be applied in centrifugal pumps without the chemical introduction, too. Thus, it is; for instance, clear that a chemical may be introduced in the annular chamber shown in Figure 4 between the wear plate 114 and the volute, and from the annular chamber to the cavity 116 via a gap or grooves similar to that/those discussed in connection with Figure 7. Naturally, the chemical introduction into the annular chamber in the volute casing may be performed by means of any conduit leading through the wall of the annular chamber.

[0039] As may be seen from the above description a novel centrifugal pump construction has been developed. While the invention has been herein described by way of examples in connection with what are at present considered to be the preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments, but is intended to cover various combinations and/or modifications of its features and other applications within the scope of the invention as defined in the appended claims.

Claims

1. A centrifugal pump for pumping a medium, the centrifugal pump having a shaft, an impeller (130, 230, 330) on the shaft and a volute casing (110, 210, 310) housing the impeller (130, 230, 330); the impeller (130, 230, 330) having working vanes (136, 236, 336) each having an outer edge (142, 242, 342) and a front edge (140, 340); the volute casing (110, 210, 310) having a circumferentially extending cavity (116, 216, 316) having a cross section formed by a wall (118, 218, 318); the wall having a rear wall section (120) with a radially inner edge (122), an inner wall section (124, 324) with an inner edge (126, 326) and an opening (119) for allowing medium pumped by the impeller to enter the cavity (116, 216, 316) in radial direction directly from the impeller (130, 230, 330); the volute casing (110, 210, 310) further having a cutwater (150) radially outside of the impeller (130, 230, 330), the cutwater (150) separating a pressure outlet duct (152) from the cavity (116, 216, 316), the pressure outlet duct (152) being located radially outside of the impeller (130, 230, 330), **characterized in that** the cross section of the cavity (116, 216, 316) is oval such that the cavity has a first axial end (116') and a second axial end (116"), the opening (119) being located at the inner circumference of the first axial end (116'), the working vanes (136, 236, 336) of the impeller (130, 230, 330) extending into the first axial end (116') of the oval cavity (116, 216, 316) via the opening (119) such that the front edges (140, 340) of the working vanes (136, 236, 336) are facing the second axial end (116") of the oval cavity (116, 216, 316) and that the pressure outlet duct (152) extends to the entire axial width of the volute casing (110, 210, 310).

2. The centrifugal pump as recited in claim 1, **characterized in that** the outer edges (142, 242, 342) of the working vanes (136, 236, 336) extend to a larger diameter than the inner edge (126, 326) of the inner wall section (124, 324) of the wall (118, 218, 318) of the circumferentially extending oval cavity (116, 216, 316).

3. The centrifugal pump as recited in claim 2, **characterized in that** the inner edge (126, 326) has a diameter, and that the diameter of the inner edge (126, 326) of the inner wall section (124, 324) of the wall

(118, 218, 318) of the oval cavity (116, 216, 316) is 80 - 90 % of the diameter of the outer edges (142, 242, 342) of the working vanes (136, 236, 336) of the impeller (130, 230, 330).

4. The centrifugal pump as recited in claim 1, **characterized in that** the impeller has a rear plate (138, 238, 338) and that the outer edge (144) of the rear plate (138, 238, 338) extends to a larger diameter than the inner edge (126, 226, 326) of the inner wall section (124, 324) of the wall (118, 218, 318) of the circumferentially extending oval cavity (116, 216, 316).

5. The centrifugal pump as recited in claim 1, **characterized in that** the inner edge (122) of the rear wall section (120) of the wall (118, 218, 318) of the circumferentially extending oval cavity (116, 216, 316) extends to a larger diameter than the inner edge (126, 326) of the inner wall section (124, 324) of the wall (118, 218, 318) of the circumferentially extending oval cavity (116, 216, 316).

6. The centrifugal pump as recited in claim 1, **characterized in that** the pressure outlet duct (152) has an opening angle α, which may be increased up to 9 - 11 degrees.

7. The centrifugal pump as recited in claim 1, **characterized in that** the volute casing (310) is provided with means (352, 354, 356) for introducing chemical to the circumferentially extending cavity (316).

8. The centrifugal pump as recited in claim 7, **characterized in that** the impeller (330) is provided with a front plate (350) and that the means for introducing chemical to the circumferentially extending oval cavity (316) comprises an annular chamber (352) between the front plate (350) and the volute casing (330).

9. The centrifugal pump as recited in claim 7, **characterized in that** the volute casing (110) is provided with a wear plate (114) and that the means for introducing chemical to the circumferentially extending oval cavity (116) comprises an annular chamber between the wear plate (114) and the volute casing (110).

10. The centrifugal pump as recited in claim 8 or 9, **characterized in that** the means for introducing chemical to the circumferentially extending cavity (316) comprises a circumferential gap (356) or substantially radial grooves between the annular chamber (352) and the circumferentially extending oval cavity (116, 316).

11. The centrifugal pump as recited in any one of the preceding claims, **characterized in that** the volute casing (110) has a cross section and that the cross section is asymmetrical in relation to an opening arranged for the impeller (130, 230, 330) in the volute casing (110, 210, 310).

12. A method of pumping a medium with the centrifugal pump of claim 1, **characterized by**

   • pumping medium by means of the impeller radially outwardly and tangentially to a first axial end of an oval cavity within the volute casing,
   • guiding medium spirally along the wall of the oval cavity up to a second axial end of the cavity and from there back to the first axial end of the oval cavity,
   • subjecting shear forces to medium by means of the front edges of the working vanes of the impeller, the front edges extending into the oval cavity and increasing the velocity and momentum of medium, and
   • guiding a part of the spirally advancing medium from the entire axial width of the oval cavity by means of a cutwater radially outwardly to the outlet duct of the centrifugal pump.

13. The method as recited in claim 14, **characterized by** introducing liquid or gaseous chemical to the spirally advancing medium at an area in front of the edges of the working vanes.

14. The method as recited in claim 15, **characterized by** introducing the chemical to the entire circumference of the inner wall section (124, 324).

15. The method as recited in claim 15, **characterized in that** the chemical is at least one of chlorine dioxide (ClO_2), hydrogen peroxide ($H2O_2$), sodium hydroxide (NaOH), sulfuric acid H_2SO_4, calcium hydroxide ($Ca(OH)_2$), Polyacrylamide (PAM), ferric sulfate ($Fe_2(SO_4)_3$) and oxygen O_2.

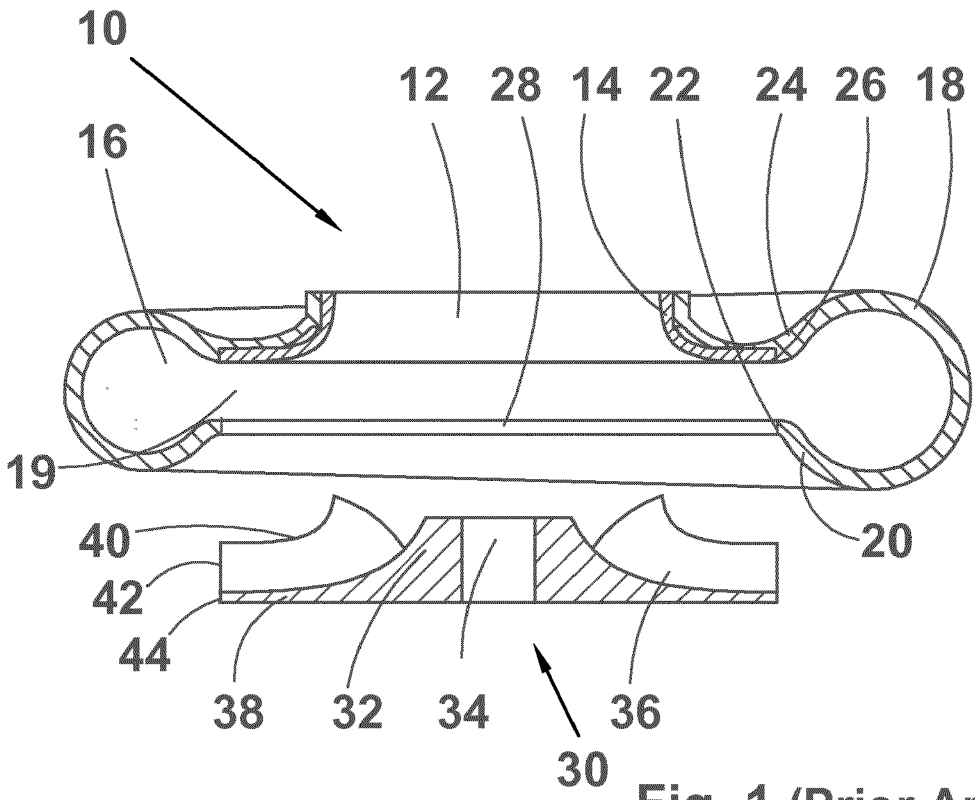

Fig. 1 (Prior Art)

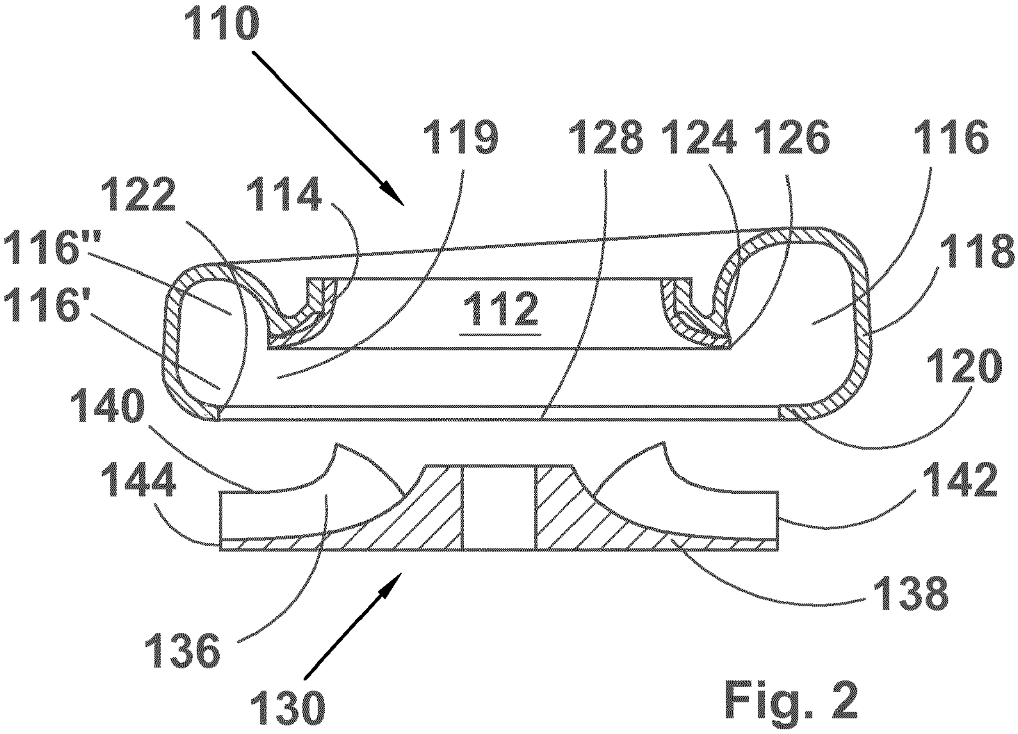

Fig. 2

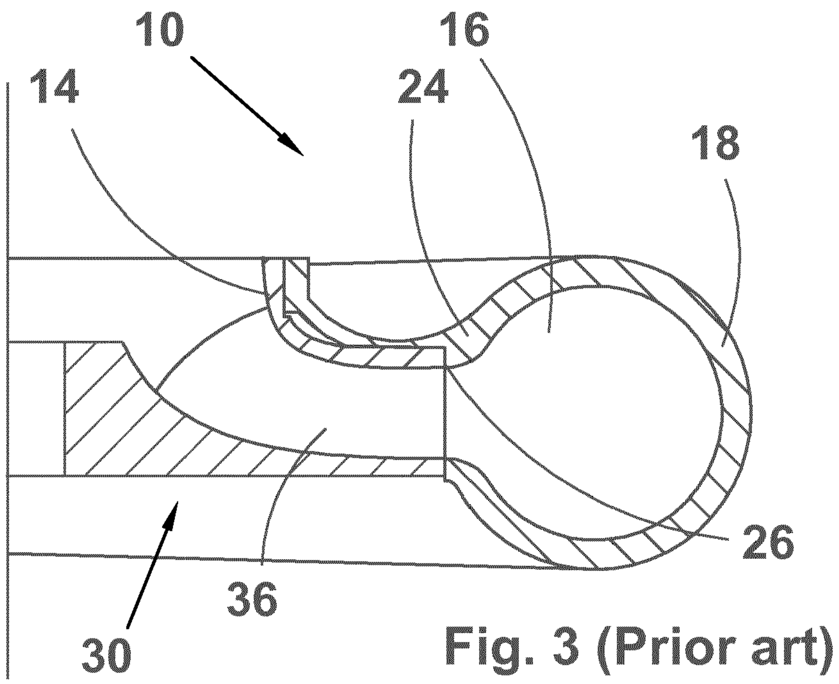

Fig. 3 (Prior art)

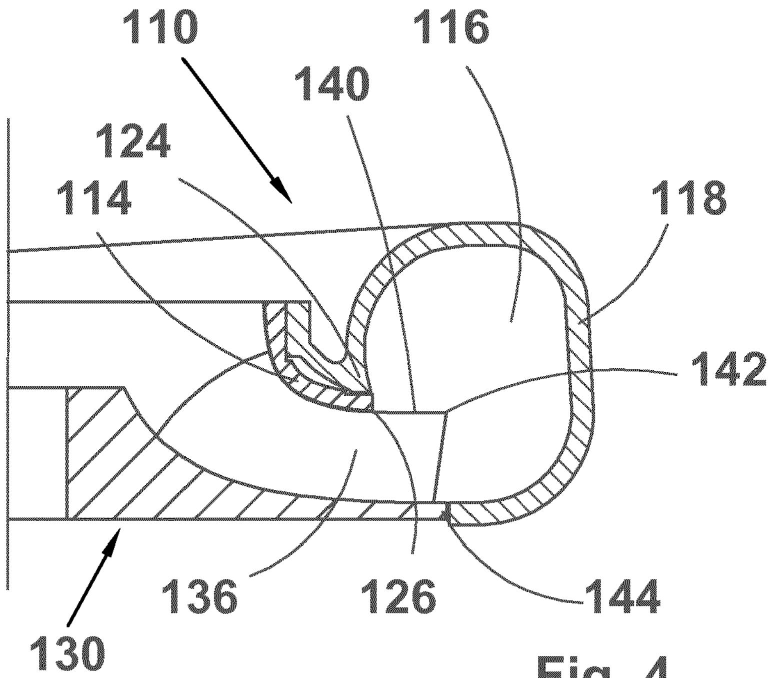

Fig. 4

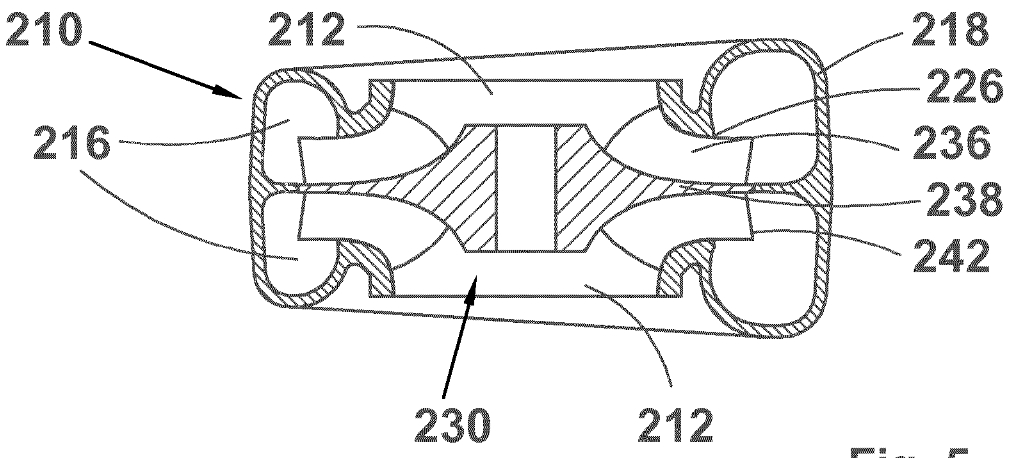
210
212
218
226
216
236
238
242
230
212

Fig. 5

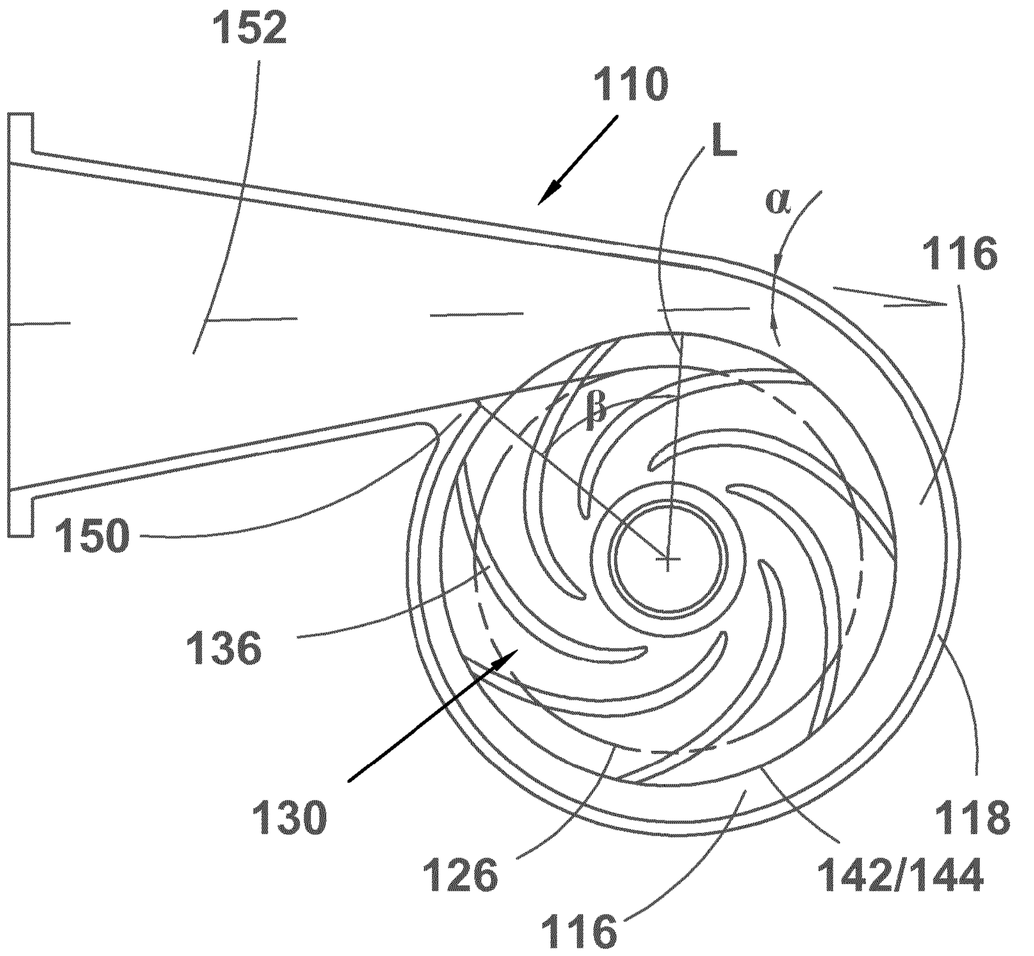
152
110
L
α
116
β
150
136
130
118
126
142/144
116

Fig. 6

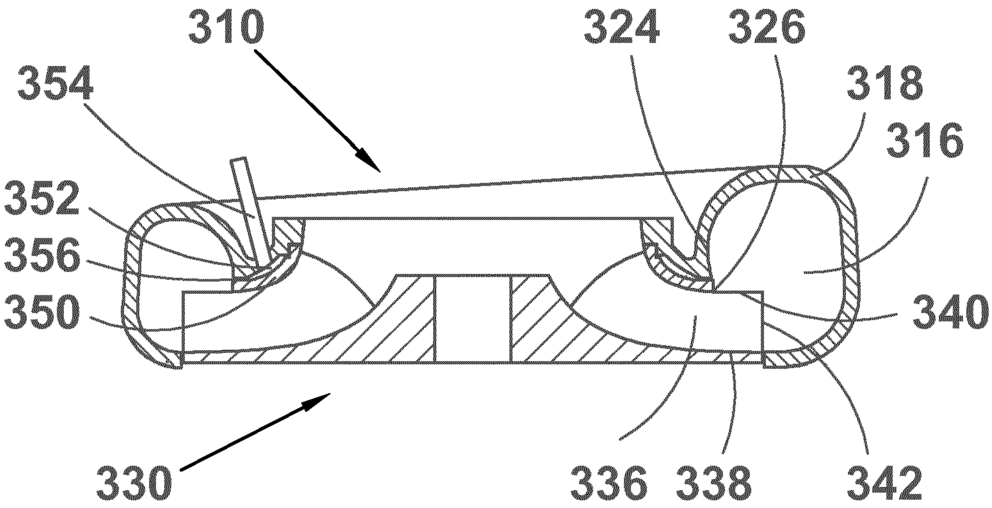

Fig. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 13 19 0981

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The present search report has been drawn up for all claims

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The Hague	7 March 2014	de Verbigier, L

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