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(54) **Turbo blood pump**

Turboblutpumpe

Turbopompe à sang

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] This invention relates to a turbo blood pump extra corporeal or implantable in a patient's body so as to conduct circulatory assistance or extra corporeal circulation of blood for a cardiopulmonary bypass operation, hemo purification, or other treatments.

2. Description of the Related Art

[0002] Conventionally, a roller blood pump for pumping out blood by compressing a tube was often used for extra corporeal circulation. However, this kind of roller pump needs a special pump segment tube to be fit thereto, and the lack of strength and durability of the tube causes problems. A further important problem is that the roller type blood pump bulky and difficult to handle. Thus it is difficult to use, for example, in an operating room. Therefore, in recent years, turbo blood pumps such as centrifugal pumps and axial flow pumps, which can be used, for example, in an operating room, have been developed. See, for example, Japanese Granted Patent No. 1914715, Japanese Unexamined Patent Publication No. 4-2358, Japanese Unexamined Patent Publication No. 6-218043, Japanese Granted Utility Model No. 1792315, Japanese Unexamined Patent Publication No. 2-99800, Japanese Unexamined Patent Publication No. 7-75667, and Japanese Unexamined Patent Publication No. 7-178165.

[0003] In the centrifugal pump liquid is fed into a casing inlet and flows substantially perpendicular to an impeller axis. In comparison in an axial flow pump liquid is fed into a casing and flows in parallel to the axis. When developing these pumps, it is necessary to design the suitable rotation number in order to feed liquid efficiently or feed liquid so as to assure a stable state in which, for example, flow separation, collision, vortex, cavitation or the like is not caused. That is, a relatively low rotation number in a range of 1,000-4,000 rpm is desired to feed liquid efficiently by means of a normal left ventricular assistance centrifugal type pump (flow rate: 5L/min, pressure head : 100 mm Hg). Further, a relatively high rotation number in a range of 9,000-30,000 rpm is desired to feed liquid efficiently by means of an axial flow pump.

[0004] The discharge rate (flow rate) of the above turbo type pumps is determined mainly by the rotation speed and the size of the impeller and the size of the casing. Thus, to assure a large discharge rate in a centrifugal type pump, the size of the pump including the impeller and casing needs to be enlarged. Generally, a centrifugal pump used for extra corporeal circulation has an impeller diameter as large as 40-80 mm and a large priming volume. However, as will be described later, eningement of the pump is not desirable.

[0005] On the other hand, because the axial flow pump ensures a larger rotation number to achieve efficient fluid feeding than the centrifugal pump, it can provide a large discharge raw if the same impeller diameter is used. However, conventional axial flow pumps could not provide a sufficient driving power for cardiopulmonary bypass, because they were about 5-16 mm in impeller diameter. Furthermore, the axial flow pump has a higher impeller rotation number than the centrifugal pump, and, therefore, blood injury such as hemolysis is more likely to occur. Thus, usually, the axial flow pump is designed so that the rotation speed is low and the impeller vane is as large as possible, in order to reduce a postibility of hemolysis. However, in this case, hydraulic efficiency drops so that advantage of the axial flow pump is not fully realized.

[0006] Further, because the conventional turbo blood pump of, for example, centrifugal pump, is connected to a driving source, many types have shaft sealing. However, a blood pump having shaft scaling is difficult to operate for more than two weeks because of durability of the shaft sealing. Also, because thrombus is likely to occur, shaft sealing is a problem in respect to anti-thrombogenicity. To solve the above problem an impeller that does not require shaft seals was developed. Such an impeller is disclosed in US Pat No. 4,507,048 issued to Belenger et al. According to this invention the upper and lower ends of the rotary shaft of the impeller are supported in the casing. External to the casing is a magnetic driving mechanism such as an electric coil which generates a rotating magnetic field for driving the impeller. A disadvantage of this invention is that rotor stability is loat when the supporting means is deformed. Deformation is caused by variations in the distance between the upper and lower bearings and the contacting pressure of the upper and lower supporting structure. Such deformation may cause hemolysis and thrombus formation in the blood pump.

[0007] EP 0452827 A2 discloses a blood pump and an extracorporeal blood circulating apparatus. The blood pump comprises a casing having an interior region, an aperture formed in an upper portion of said casing defining a blood inlet, and an aperture formed in a lower portion of said casing defining a blood outiet, an impeller rotatably mounted about a vertical axis within said interior region, said impeller including a rotary shaft and at least one vane depending therefrom, and driving means for rotating said impeller about said rotary shaft.

SUMMARY OF THE INVENTION

[0008] Accordingly, an object of the present invention is to provide a blood pump which can be installed in, for example, an operating room, and will not disturb the operation procedure. Another object of the present invention is to provide a small-size, implantable blood pump which can be implanted in the body and will reduce anatomical limitation at the time of implantation, thereby simplifying operation. Yet another object of the present invention is to provide a blood pump which has a sufficient discharge rate and driving power - thereby achieving efficient feeding of liquid. A further object of the present invention is to provide a blood pump which reduces an influence upon blood due to dynamic action such as shear stress and heat generation, thereby reducing damage upon blood such as hemolysis. A still further object of the present invention is to provide a blood pump which limits the formation of thrombus and is highly durable.

[0009] The objects are achieved by a turbo blood pump comprising:

a) a casing having an interior region, an aperture formed in an upper portion of said casing defining a blood inlet, and an aperture formed in a lower portion of said casing defining a blood outlet;

b) an impeller rotatably mounted about a vertical axis within said interior region, said impeller including a rotary shaft and at least one vane depending therefrom, said at least one vane extending radially less near said blood inlet than near said blood outlet and having a three-dimensional structure formed of twisted curved faces, which is not parallel to the rotary axis of the impeller, the base of said at least one vane forming an exterior angle δ of less than 65° with the axis of said rotary shaft and,

c) a driving means for rotating said impeller about said rotary shaft.

[0010] Preferably, the distal portion of said at least one vane includes a vane top face angle α and a vane base angle β and said top face angle is unequal to said vane base angle.

[0011] Still preferred, the distal portion of said at least one vane includes a vane top face angle and a vane base angle and said top face angle is smaller than said vane base angle.

[0012] According to the invention, it is further preferred that the upper portion of said impeller rotary shaft is rotatably supported in a pivot bearing structure and the lower portion of said impeller rotary shaft is rotatably supported in a sliding bearing structure, said sliding bearing of the cylindrical face containing type, and wherein said means for rotating said impeller includes a driven magnet mounted on said at least one vane and a driving magnet mounted radially adjacent said driven magnet and outside said casing, whereby said driven magnet is magnetically coupled with said driving magnet.

[0013] Preferably, said at least one vane of said impeller is of the full-open type.

[0014] Still preferred, said interior region of said casing gradually expands from said blood inlet to said blood outlet.

[0015] Finally it is preferred that the thickness of the vane is made to vary gradually from the proximal end of the vane to the distal end thereof.

[0016] The above and other features of the subject invention will be made more readily apparent to those having ordinary skill in the art from the following detailed description of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] Although the turbo blood pump of the present invention can be embodied in various ways in terms of its components and allocation, preferred drawings and embodiments are described and illustrated below:

Fig. 1 is a side elevational view in cross-section of a turbo blood pump according to the present invention with magnetic coupling in the radial direction;

Fig. 2 is a perspective view of a rotary shaft and a vane of an impeller, the vane having three-dimensional structure formed by twisted curved faces;

Fig. 3 is a side elevational view in cross-section of another turbo blood pump constricted in accordance with a preferred embodiment of the subject invention with magnetic coupling in the radial direction;

Fig. 4 is a side elevational view in cross-section of another turbo blood pump constructed in accordance with a preferred embodiment of the subject invention with magnetic coupling in the axial direction; and

Fig. 5 is a top plan view of the impeller of FIG. 2 as viewed along line 5-5 having four vanes attached and illustrating the relationship between vane top face angle (α) and the vane base angle (β).

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0018] Features and preferred embodiments of a turbo blood pump of the present invention will be described in detail with reference to the accompanying drawings.

1. Pump flow type

[0019] Turbo pumps may be generally classified as centrifugal flow pumps, a mixed flow pumps, or axial flow pumps. The turbo blood pump of the present invention will be described in detail with respect to each component.

[0020] With respect to small size and discharge rate, the mixed flow pump is most desirable. Referring to FIG. 1, there is illustrated a mixed flow pump of the present invention. In the mixed flow pump, blood in an impeller flows neither parallel or perpendicular to the pump axis, but in an oblique direction as illustrated by the arrows. The mixed flow pump utilizes a centrifugal force so as to give energy to fluid such as blood. Thus the impeller of the mixed flow pump has a larger diameter at its vane exit B than at its vane entrance A - unlike the axial flow pump. The bottom of the vane 22 has an exterior angle δ of $0^\circ < \delta < 65^\circ$ with the axis of the impeller shaft. In viewpoints of efficiency of flow and damage upon fluid, the above angle δ is preferred to be $25^\circ < \delta < 65^\circ$. The optimum specific speed of the mixed flow type blood pump is higher than the centrifugal pump, thus a higher rotation number and thereby a higher efficiency can be obtained. Because the higher rotation number is achieved, the size of the impeller and casing can be reduced, so that reduction of the pump size and assurance of the large discharge rate are achieved without decreasing the efficiency.

2. Impeller Structure**a. Three-dimensional structure of the vanes**

[0021] Because, in the turbo blood pump according to the present invention, the upper portion and lower portion of the impeller vane have different diameters A and B at both the entrance and exit, respectively, as a result of considering optimization of blood flow in the pump, it has been found that the vane shape is desired to be a three-dimensional structure vane, which is not parallel to the rotary axis of the impeller. These vane structures are favorable in either the mixed flow pump or the non-mixed flow pump, and particularly it has been recognized that they are further favorable in the mixed flow pump. As shown in a plan view in axial direction (See FIG. 5), the upper end of the vane 7 reaches a more outside circumference (virtual circumference D) than the circumference (virtual circumference C) of bottom end thereof.

[0022] With continuing reference to FIG. 5 there is illustrated the vane top face angle α and the vane base angle β . The top face angle α is defined as the angle formed between a line tangent to the top face of said vane at the upper end point 7 on virtual circumference D and a line tangent to the circle formed by the impeller vane at upper end point 7. The vane base angle β is defined as the angle formed between a line tangent to the base of said vane at the base end point 8 on virtual circumference C and a line tangent to the circle formed by the impeller vane at base end point 8.

[0023] The turbo blood pump of the present invention has such a three-dimensional structure that the impeller vane is twisted with respect to the rotational axis as described above. Thus, blood flow disturbances such as flow separation, collision, vortex formation, cavitation on the like are reduced. That is the blood flow is made more efficient. Further, if the blood flow is made efficient, shear stress of blood is reduced, so that generation of heat due to energy loss in the pump is suppressed. As a result, hemolysis is suppressed, the durability of the impeller vane and rotary shaft subjected to high speed rotation is improved, formation of thrombus is suppressed and other effects are produced.

b. Vane diameter

[0024] Referring to FIG. 1, the diameter B of the vane of the turbo blood pump of the present invention is preferred to be in a range of 4-80 mm. A range of 15-40 mm is further preferred. Such a blood pump in which the impeller vane diameter B is 15-30 mm is most suitable for use in long-term implantation type artificial heart. Further, a blood pump having a diameter B of 20-40 mm is suitable for extra corporeal circulation or paracorporeal circulatory assistance because it can generate a higher pressure head than the former.

c. Vane material and thickness

[0025] The material forming the vanes is required to have the following characteristics; (1) harmless to the human body (excellent bio-compatibility), (2) excellent long-term durability, (3) ability of being precision processed, (4) excellent in hemo-compatibility such as anti-thrombogenicity, (5) appropriate hardness, etc. For example, synthetic resin such

as acrylic, polyacrilate, polymetacrilate, polycarbonate and fluoresein and stainless steel, titanium, titanium alloy, fine ceramics or the like are preferable materials.

[0026] If the thickness of the vane is too small, there is a problem in strength and durability. If the thickness thereof is too large, too much driving energy is loaded thereon. The preferred thickness of the vane is 1.5-2.0 mm when using polyacrilate and polymetacrilate, 1.0-1.5 mm when using polycarbonate (which has a higher strength than the former), and 0.5-1.5 mm when using stainless, titanium, titanium alloy or the like.

[0027] If the thickness of the vane is made to vary gradually from the proximal end of the vane to the distal thereof, it is effective for maintaining a flow path in the pump or ensuring efficient flow. By gradually thinning the vane from the proximal to the distal end, flow separation can be reduced so that turbulent flow near the exit is reduced. By gradually thickening the vane structure, the percentage of blood flow at the entrance can be increased.

d. Number of vanes

[0028] Usually there are provided 2-8 vanes, however 3 vanes are preferred. A blood pump having an impeller comprising one vane cannot produce a stable driving force and a blood pump having nine or more vanes is difficult to produce.

e. Other impeller structure

[0029] In the turbo blood pump of the present invention, a full-open impeller is employed. A full-open impeller is one in which there is no disc attached to the upper and lower portion of the vanes. As a result, a structure without blood stagnation is provided, so that a place likely to form thrombus is eliminated, thereby achieving excellent anti-thrombogenicity.

3. Impeller shaft and bearing structures, and magnet coupling system for driving the impeller

a. Material forming the shaft

[0030] The impeller shaft is to be formed of material having the following characteristic; (1) excellent in hemo-compatibility such as anti-thrombogenicity, (2) suitable hardness, and the like, and for example, stainless steel, titanium, ceramics or the like is preferable. A bearing for supporting such a shaft is desired to be formed of material having excellent anti-abrasion in addition to the above characteristics. For example, highly durable plastic such as ultra-high density polyethylene or ultra-high molecular weight polyolefin "Lubmer™ :manufactured by MITUI SEKI KAGAKU Co. Ltd".

b. Bearing structure and magnet coupling system

[0031] As shown in Fig. 3, a magnet casing 14 is mounted to the impeller vane 4 and a driven magnet 15 is mounted within the magnet casing 14. The driven magnet 15 is magnetically coupled with a driving magnet 16 mounted outside the magnet casing 14 and radially adjacent the driven magnet 15. As a result, a force of the magnetic coupling is not applied to the shaft 12 and the pivotal bearing 9 and sliding bearing 13 so that no unnecessary stress is applied between the shaft and the bearing. Thus, a relation between an upper shaft end 17 and an upper bearing 9 is desired to be of pin-point contacting or pivot bearing in which little abrasion or heat is produced. However, when the driving magnet and the driven magnet are magnetically coupled with each other in the direction of the radius, there sometimes occurs a deflection and become unstable in the radius direction of the shaft. Thus, a lower shaft end 18 is structured to be in cylindrical contacting relationship with the sliding bearing 13. As a result, the lower bearing provides a fail-safe function.

[0032] Further, as shown in Fig. 4, it is permissible to place the driven magnet 15 directly on the impeller vane and magnetically couple the driven magnet 15 with the driving magnet 16 located out of the casing 3, in the vertical direction relative to the impeller shaft. When they are magnetically coupled with each other in the vertical direction, the lower shaft end 18 is never deflected in the radius direction of the shaft. Thus, like the relation between the upper shaft end 17 and the upper bearing 9, it is permissible to couple the lower shaft end 18 and the lower bearing 13 with each other in a pin-point contacting or pivot bearing structure.

c. Magnet material

[0033] It is desirable that the driven magnet 15 and driving magnet 16 are formed of material which reduces inertia mass of the impeller and raises pump speed response, so as to increase the stability of impeller rotation and durability of the shaft, and further reduce shearing stresses in the fluid in the pump, thereby reducing hemolysis, and reducing

the size of the pump. To satisfy the above requirements, it is preferable that the magnet be a rare earth magnet, for example, neodymium, samarium cobalt or the like.

4. Casing and other blood pump components

[0034] In the blood pump of the present invention, the space (called volute) formed between impeller vanes and the interior region of the casing should be maintained as small as possible. Although the efficiency of the pump is increased as the space is reduced, too small a space tends to cause blood damage due to the shearing forces produced there between. The desirable clearance has been found to be between 0.1-1.0 mm. Blood flow is also optimized when the casing is formed such that its cross-sectional area is gradually expanded in the flow direction toward the blood exit.

[0035] Also, because joints between the casing and the bearings can have microscopic gaps, thrombus formation and hemolysis can easily occur. For this reason, it is desirable that the bearings described above are formed integrally with the casing.

5. Impeller production method

a. Synthetic resin produced impeller

[0036] If the material of the vane is synthetic resin such as acrylic, polyacrylic, polymetacrylate, polycarbonate, fluoeresin or the like, the impeller can be produced by any appropriate method described below. For example, it is permissible to mold a predetermined shape vane by injection molding polycarbonate and then bond the magnet casing to this vane by adhesive. Or it is permissible to form the vanes and the magnet casing integrally.

b. Metallic impeller

[0037] If the material of the vanes are metal such as stainless steel, titanium, titanium alloy or the like, the impeller can be produced in the same method as the above synthetic resin type. For example, it is possible to produce the vane, shaft and magnet casing independently or integrally by lost-wax molding. In lost-wax molding, a male die is made of wax which is replaced by metal or the like. Further, the vane, shaft and magnet casing can be integrally produced. Or the impeller can be produced by cutting stainless steel, titanium, titanium alloy or the like integrally. While the former is suitable for mass production, the latter is suitable for small quantity production of multiple product types.

6. Preferred embodiment

[0038] A preferred embodiment of the turbo blood pump according to the present invention will be described hereinbelow.

[0039] FIG. 1 schematically shows a construction of the present invention. The casing 3 comprises an inlet 1 at its upper end and an outlet 2 at the bottom thereof. In a plurality of the vanes of the impeller, driven magnets 15 in the magnet casing 14 at the lower portion is magnetically coupled with the driving magnet 16 located out of the casing 3. Driving magnet 16 is rotated by a motor placed out of the pump. As a result, the impeller containing the driven magnet 15 is rotated so as to supply energy to the blood. The impeller is supported by the shaft 12 and the shaft 12 is supported by the upper bearing 9 and the lower bearing 13. The upper bearing 9 is supported by an upper bearing holder 10.

[0040] With continuing reference to FIG. 1 a top face of the vane connecting the upper end 5 of the vane at the entrance and the upper end 7 of the vane at the exit has an angle ϕ of 45° with respect to the axis of the shaft 12. A bottom face of the vane connecting the lower end 6 of the vane at the entrance and the lower end 8 of the vane at the exit has an angle δ of 30° with respect to the axis of the shaft 12. Consequently, fluid flow within the impeller becomes an oblique flow which is not perpendicular nor parallel to the shaft 12.

[0041] Referring now to FIGS. 2 and 5, the upper end 7 and the lower end 8 have different diameters at the distal end of the impeller vane. In addition, the impeller vane has been shaped so as to optimize the flow. More specifically, the vane top face angle α - the angle of the upper end of the vane at the exit, relative to circumference D - is designed so as to be smaller than the vane base angle β - the angle of the lower end of the vane at the exit, relative to circumference C. According to the instant embodiment, the top face angle α is 11° and the base angle β is 13° . In the turbo blood pump of the present invention, the impeller vanes are formed in a three-dimensional structure formed of twisted faces, in order to ensure flow efficiency and reduce blood injury. That is, in the instant embodiment, the vane structure 5 described previously is employed. FIG. 2 shows a perspective view of an example of the impeller vane formed in the three-dimensional structure formed of the above twisted faces.

[0042] Referring to FIG. 1, the driven magnet 15 mounted on the impeller 4 and the driving magnet 16 mounted outside the casing 3 are magnetically coupled with each other radially relative to the rotary shaft 12. This coupling

force produces no axial forces so that the rotary shaft and the bearing is not loaded, thereby improving the durability of the rotary shaft and the bearing. The upper bearing 9 is made of high density polyethylene which is highly durable synthetic resin.

[0043] According to the instant embodiment, fine ceramic made balls 11 are embedded in the upper end of the shaft and are made to contact the bearing 9 in pin-point contacting relationship, thereby improving the durability. The entire impeller is formed of stainless steel. The lower bearing 13 is formed in a cylindrical shape and made of a high durability synthetic resin such as high density polyethylene. The impeller shaft 12 is formed in a cylindrical shape corresponding to the shape of the bearing 13. The impeller shaft 12 is supported in face contacting relationship with the lower bearing 13. Because of this face contacting relationship, even if the upper bearing 9 becomes slightly abraded, the lower shaft end 18 will not slip out of the lower bearing 13. This ensures a fail-safe function, thereby contributing to the long-term stability of the rotary shaft.

[0044] According to the instant embodiment, both the driving magnet 16 and driven magnet 15 are made of neodymium. If an electric magnet is installed instead of the driving magnet 16, the driven magnet 15 is rotated by that electric magnet, and an independent motor is not required. Thus, a smaller size, more durable pump is realized.

EXAMPLES

[0045] All of the examples provided below are intended to be illustrative of several aspects of the invention. They are not intended to limit the scope or the underlying principles of the invention in any way.

EXAMPLE 1

[0046] A volute type mixed flow pump was used. The height thereof including the casing is 38 mm and the diameter thereof is 48 mm. The impeller is of full-open type to improve antithrombogenicity, having its maximum diameter of 20 mm, and is driven by magnetic coupling having no axial seal. This blood pump shows a discharge rate of 5 l/min at a pressure head of 100 mm Hg under 5,800 rpm, thereby indicating a sufficient performance for replacing the entire cardiac function. The maximum efficient point of the pump is 6.9 l/min in flow rate, 136 mm Hg at the pressure head, and 7,000 rpm in rotation number, so that its maximum total hydraulic efficiency is 66% and specific velocity calculated from the maximum efficient point is 368.

EXAMPLE 2

Hemolysis test

[0047] With heparinized fresh bovine blood being used at a blood priming volume of 400 ml, hemolysis test was conducted under a condition in which the flow rate was 5 l/min, at pressure head of 100 mm Hg for 0-5 hours. The same test was conducted by means of a commercially available Delphin pump. Table 1 shows these results, according to which hemolytic index is 0.015g/100 l, which is less than half the hemolytic index of 0.033 g of the Delphin pump.

Table. 1

(Result of Hemolysis test)				
Blood	Fresh bovine blood			
Priming volume (ml)	400			
Flow rate(ml/min)	5,000			
Pressure head (mmHg)	100			
Pump	A mixed flow pump		Delphin pump	
Time (min)	Ht	Free Hb	Ht	Free Hb
0	32.4	10	32.1	8
30	31.5	20	31.5	24
60	31.9	27	31.9	41
120	32.8	51	30.9	76
180	33.7	62	31.6	118
240	32.4	79	31.9	155

Table. 1 (continued)

(Result of Hemolysis test)				
Pump	A mixed flow pump		Delphin pump	
Time (min)	Ht	Free Hb	Ht	Free Hb
$HI = (100 - Ht)CV/100QT$ HI : Hemolysis index Ht : Hematocrit (%) C : Increase of free hemoglobin (mg/dl) V : Priming volume (ml) Q : Blood Flow rate (ml/min) T : Time (min)				

Claims**1.** A turbo blood pump comprising:

a) a casing (3) having an interior region, an aperture formed in an upper portion of said casing (3) defining a blood inlet (1), and an aperture formed in a lower portion of said casing defining a blood outlet (2);

b) an impeller rotatably mounted about a vertical axis within said interior region, said impeller including a rotary shaft (12) and at least one vane (4) depending therefrom, said at least one vane (4) extending radially less near said blood inlet than near said blood outlet and having a three-dimensional structure formed of twisted curved faces, which is not parallel to the rotary axis of the impeller, the base (22) of said at least one vane (4) forming an exterior angle δ of less than 65° with the axis of said rotary shaft (12), and

c) a driving means (15, 16) for rotating said impeller about said rotary shaft (12).

2. The turbo blood pump according to claim 1, wherein said at least one vane (4) includes at its distal portion a vane top face angle α , formed between a line tangent to the vane top face at vane upper end point (7) and a line tangent to a virtual circumference formed by the vane at said vane upper end point (7), and a vane base angle β , formed between a line tangent to the vane base at vane base end point (8) and a line tangent to a virtual circumference formed by the vane at said vane base end point (8), and said top face angle α is unequal to said vane base angle β .

3. The turbo blood pump according to claim 1, wherein said at least one vane (4) includes at its distal portion a vane top face angle α , formed between a line tangent to the vane top face at vane upper end point (7) and a line tangent to a virtual circumference formed by the vane at said vane upper end point (7), and a vane base angle β , formed between a line tangent to the vane base at vane base end point (8) and a line tangent to a virtual circumference formed by the vane at said vane base end point (8), and said top face angle α is smaller than said vane base angle β .

4. The turbo blood pump according to claim 1, wherein the upper portion of said impeller rotary shaft (12) is rotatably supported in a pivot (9) bearing structure and the lower portion of said impeller rotary shaft (12) is rotatably supported in a sliding (13) bearing structure, said sliding bearing of the cylindrical face containing type, and wherein said means for rotating said impeller includes a driven magnet (15) mounted on said at least one vane (4) and a driving magnet (16) mounted radially adjacent said driven magnet and outside said casing (14), whereby said driven magnet (15) is magnetically coupled with said driving magnet (16).

5. The turbo blood pump according to claim 1, wherein said at least one vane (4) of said impeller is of the full-open type.

6. The turbo blood pump according to claim 1, wherein said interior region of said casing (3) gradually expands from said blood inlet (1) to said blood outlet (2).

7. The turbo blood pump according to claim 1, wherein the thickness of the vane (4) is made to vary gradually from the proximal end of the vane (4) to the distal end thereof.

Patentansprüche

1. Turboblutpumpe, welche umfaßt:

- 5 a) ein Gehäuse (3) mit einem Innenbereich, einer Öffnung, die in einem oberen Bereich des Gehäuses (3) gebildet ist, die einen Bluteinlaß (1) definiert, und einer Öffnung, die in einem unteren Bereich des Gehäuses gebildet ist, die einen Blutauslaß (2) definiert;
- 10 b) einen Impellerrührer, der drehbar um eine vertikale Achse innerhalb des Innenbereichs montiert ist, wobei der Impellerrührer eine Drehwelle (12) und wenigstens einen Flügel (4) umfaßt, der von dieser absteht, wobei der wenigstens eine Flügel (4) sich radial weniger nahe dem Bluteinlaß als nahe dem Blutauslaß erstreckt und eine dreidimensionale Struktur aufweist, die aus verdrehten, gekrümmten Vorderflächen gebildet ist, welche nicht parallel zu der Drehachse des Impellerrührers ist, wobei die Basis (22) des wenigstens einen Flügels (4) einen Außenwinkel δ von weniger als 65° mit der Achse der Drehwelle (12) bildet, und
- 15 c) ein Antriebsmittel (15, 16) zum Drehen des Impellerrührers um die Drehwelle (12).
2. Turboblutpumpe nach Anspruch 1, **dadurch gekennzeichnet, daß** der wenigstens eine Flügel (4) an seinem distalen Bereich einen Flügelobervorderflächenwinkel α , der zwischen einer Tangenslinie zu der Flügelobervorderfläche am oberen Flügelendpunkt (7) und einer Tangenslinie zu einem virtuellen Umfang gebildet wird, der durch den Flügel an dem oberen Flügelendpunkt (7) gebildet ist, und einen Flügelbasiswinkel β einschließt, der zwischen einer Tangenslinie zu der Flügelbasis am Flügelbasisendpunkt (8) und einer Tangenslinie zu einem virtuellen Umfang gebildet wird, der durch den Flügel am Flügelbasisendpunkt (8) gebildet ist, und wobei der Obervorderflächenwinkel α ungleich ist zu dem Flügelbasiswinkel β .
- 25 3. Turboblutpumpe nach Anspruch 1, **dadurch gekennzeichnet, daß** der wenigstens eine Flügel (4) an seinem distalen Bereich einen Flügelvorderoberflächenwinkel α einschließt, der zwischen einer Tangenslinie zu der Flügelobervorderfläche am oberen Flügelendpunkt (7) und einer Tangenslinie zu einem virtuellen Umfang gebildet wird, der durch den Flügel am oberen Flügelendpunkt (7) gebildet ist, und einen Flügelbasiswinkel β , der zwischen einer Tangenslinie zu der Flügelbasis am Flügelbasisendpunkt (8) und einer Tangenslinie zu einem virtuellen Umfang gebildet wird, der durch den Flügel am Flügelbasisendpunkt (8) gebildet ist, und wobei der Obervorderflächenwinkel α kleiner ist als der Flügelbasiswinkel β .
- 30 4. Turboblutpumpe nach Anspruch 1, **dadurch gekennzeichnet, daß** der obere Bereich der Impellerrührerdrehwelle (12) drehbar gehalten ist in einer Drehlagerstruktur (9) und der untere Bereich der Impellerrührerdrehwelle (12) drehbar gehalten ist in einer Gleitlagerstruktur (13), wobei das Gleitlager vom Typ ist, das zylindrische Vorderflächen enthält und wobei das Mittel zum Drehen des Impellerrührers einen angetriebenen Magneten (15) einschließt, der auf dem wenigstens einen Flügel (4) montiert ist, und einen Antriebsmagneten (16), der radial benachbart dem angetriebenen Magneten und außerhalb des Gehäuses (14) montiert ist, wodurch der angetriebene Magnet (15) magnetisch mit dem Antriebsmagneten (16) gekoppelt ist.
- 40 5. Turboblutpumpe nach Anspruch 1, **dadurch gekennzeichnet, daß** der wenigstens eine Flügel (4) des Impellerrührers vom vollständig offenen Typ ist.
- 45 6. Turboblutpumpe nach Anspruch 1, **dadurch gekennzeichnet, daß** der Innenbereich des Gehäuses (3) sich allmählich von dem Bluteinlaß (1) zu dem Blutauslaß (2) ausdehnt.
- 50 7. Turboblutpumpe nach Anspruch 1, **dadurch gekennzeichnet, daß** die Dicke des Flügels (4) eingestellt ist, um allmählich von dem proximalen Ende des Flügels (4) zu dem distalen Ende desselben zu variieren.

Revendications

- 55 1. Turbopompe à sang comprenant :
- a) un boîtier (3) ayant une région intérieure, une ouverture formée dans une partie supérieure dudit boîtier (3) définissant une entrée de sang (1), et une ouverture formée dans une partie inférieure dudit boîtier définissant

une sortie de sang (2) ;

b) un agitateur monté de manière rotative autour d'un axe vertical dans ladite région intérieure, ledit agitateur comprenant un arbre rotatif (12) et au moins une aube (4) dépendant de celui-ci, ladite au moins une aube (4) s'étendant de manière radiale moins près de ladite entrée de sang que de ladite sortie de sang et ayant une structure tridimensionnelle formée de faces incurvées tordues, qui n'est pas parallèle à l'axe rotatif de l'agitateur, la base (22) de ladite au moins une aube (4) formant un angle extérieur δ inférieur à 65° avec l'axe dudit arbre rotatif (12), et

c) des moyens d'entraînement (15, 16) pour faire tourner ledit agitateur autour dudit arbre rotatif (12).

2. Turbopompe à sang selon la revendication 1, dans laquelle ladite au moins une aube (4) comprend au niveau de sa partie distale, un angle de face supérieure d'aube α , formé entre une ligne tangente à la face supérieure d'aube au niveau d'un point d'extrémité supérieur (7) de l'aube et une ligne tangente à une circonférence virtuelle formée par l'aube au niveau dudit point d'extrémité supérieur (7) de l'aube, et un angle de base d'aube β , formé entre une ligne tangente à la base de l'aube au niveau du point d'extrémité de base (8) de l'aube et une ligne tangente à une circonférence virtuelle formée par l'aube au niveau dudit point d'extrémité de base (8) de l'aube, et ledit angle de face supérieure α n'est pas égal audit angle de base d'aube β .
3. Turbopompe à sang selon la revendication 1, dans laquelle ladite au moins une aube (4) comprend au niveau de sa partie distale, un angle de face supérieure d'aube α , formé entre une ligne tangente à la face supérieure d'aube au niveau d'un point d'extrémité supérieur (7) de l'aube et une ligne tangente à une circonférence virtuelle formée par l'aube au niveau dudit point d'extrémité supérieur (7) de l'aube, et un angle de base d'aube β , formé entre une ligne tangente à la base de l'aube au niveau du point d'extrémité de base (8) de l'aube et une ligne tangente à une circonférence virtuelle formée par l'aube au niveau dudit point d'extrémité de base (8) de l'aube, et ledit angle de face supérieure α est inférieur audit angle de base d'aube β .
4. Turbopompe à sang selon la revendication 1, dans laquelle la partie supérieure dudit arbre rotatif (12) d'agitateur est supportée de manière rotative dans une structure de palier à pivot (9) et la partie inférieure dudit arbre rotatif (12) d'agitateur est supportée de manière rotative dans une structure de palier lisse (13), ledit palier lisse du type contenant la face cylindrique, et
dans laquelle lesdits moyens pour faire tourner ledit agitateur comprennent un aimant d'entraîné (15) monté sur ladite au moins une aube (4) et un aimant d'entraînement (16) monté de manière radiale adjacent audit aimant entraîné et à l'extérieur dudit boîtier (14), moyennant quoi ledit aimant entraîné (15) est couplé magnétiquement audit aimant d'entraînement (16).
5. Turbopompe à sang selon la revendication 1, dans laquelle ladite au moins une aube (4) dudit agitateur est du type complètement ouverte.
6. Turbopompe à sang selon la revendication 1, dans laquelle ladite région intérieure dudit boîtier (3) se dilate progressivement de ladite entrée de sang (1) à ladite sortie de sang (2).
7. Turbopompe à sang selon la revendication 1, dans laquelle l'épaisseur de l'aube (4) est réalisée pour varier progressivement de l'extrémité proximale de l'aube (4) à son extrémité distale.

Fig. 3

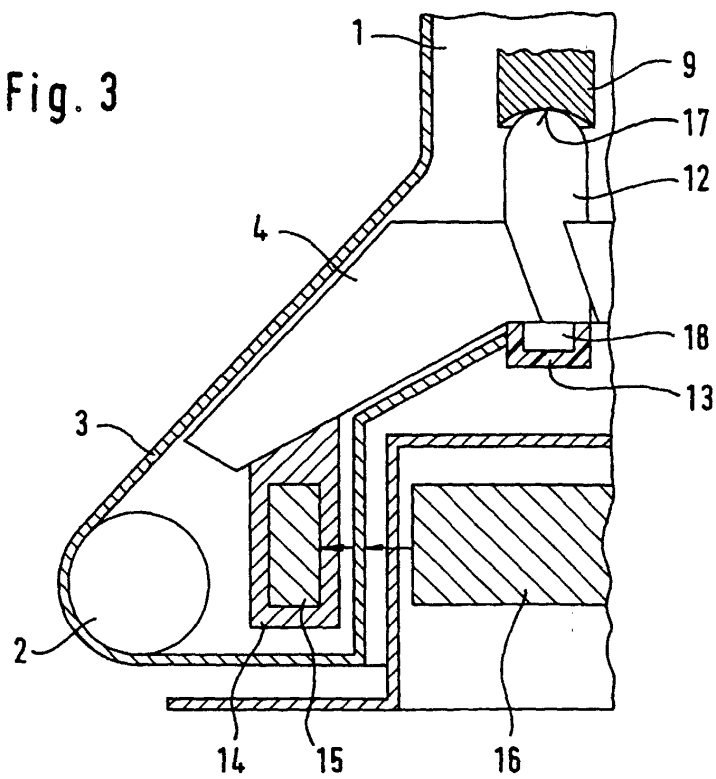
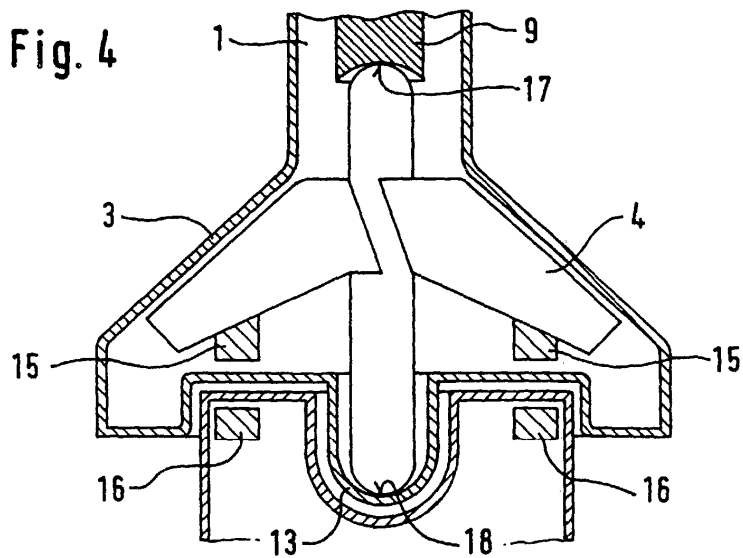


Fig. 4



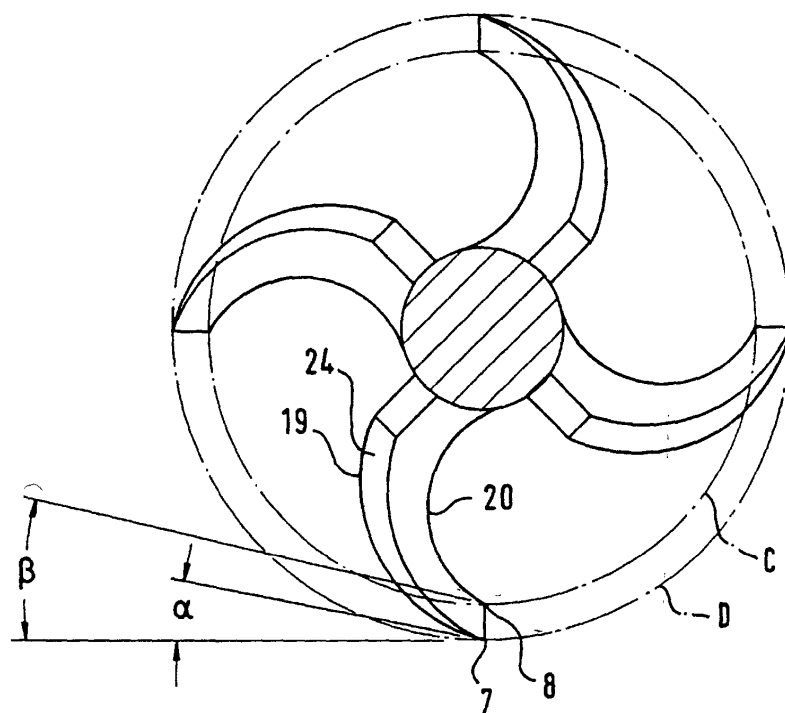


Fig. 5