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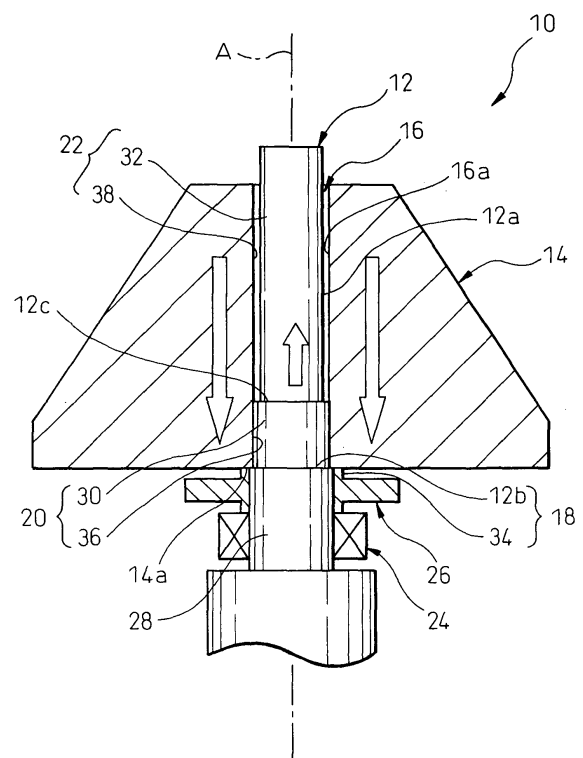
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(54) **Structure for joining impeller to rotatable shaft**

(57) A fluid machine including a shaft and an impeller, wherein the impeller has a shaft bore into which the shaft is inserted, and wherein the impeller is coupled to the shaft by an interference fit. The fluid machine further includes a positioning part provided between the shaft and the impeller, for positioning the impeller at a predetermined position on the shaft; a fitting part provided inside the shaft bore and adjacent to the positioning part, for forming the interference fit between the shaft and the impeller; and a loose-insertion part provided inside the shaft bore and adjacent to the fitting part, for forming a clearance between the shaft and the impeller.

Fig.1



Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention generally relates to fluid machinery and, more particularly, to a fluid machine including a shaft and an impeller coupled to each other by an interference fit.

2. Description of the Related Art

[0002] In a fluid machine of a high-speed rotation type, such as a blower used in a laser oscillator, it is required to firmly or fixedly attach an impeller to a shaft (or a rotary shaft) with high positional accuracy. To this end, conventionally, the impeller is fitted to the shaft by a shrinkage fit, so as to prevent a relative positional deviation in a circumferential direction of the impeller and the shaft, which may occur during the high-speed rotation thereof, and to allow them to rotate stably at high speed, as described in, e.g., Japanese Unexamined Patent Publication (Kokai) No. 7-063193 (JP-A-7-063193).

[0003] Further, there is known a configuration in which the impeller is fitted, at only a part of a shaft bore thereof, to the shaft by the shrinkage fit, as described in Japanese Unexamined Patent Publication 2004-060460 (JP-A-2004-060460). JP-A-2004-060460 also describes a technique in which the impeller is mounted on a surface plate with the gas-intake side of the impeller being directed upward and, in this state, a fitting part provided at the gas-intake side in the shaft bore of the impeller is subjected to heat to increase the inner diameter of the fitting part and, after the shaft is inserted downward into the shaft bore up to a predetermined position from an upper side of the impeller, the heat is removed to complete the shrinkage fit.

[0004] In a conventional fluid machine in which the impeller is fitted to the shaft by the shrinkage fit, a relative fixing position between the impeller and the shaft is typically determined based on a point at which the impeller is first engaged with the shaft during the shrinkage of the impeller and, thereafter, the impeller completely shrinks to be firmly fixed to the shaft. In this connection, it is generally difficult to accurately estimate the fixing position of the impeller on the shaft (i.e., the position of the first engagement point) due to, e.g., uneven machining accuracy of the impeller and the shaft. Therefore, it is difficult to accurately locate and fix the impeller at a predetermined position in an axial direction on the shaft and, as a result, the operational reliability and/or performance of the fluid machine may be adversely affected.

[0005] For example, in a configuration in which a shaft seal and/or a bearing are mounted adjacent to the impeller, if the axial position of the impeller on the shaft is deviated from a set position, the axial positions of the shaft seal and the bearing are also deviated from set

positions thereof accordingly. In particular, if the positional deviation of the bearing is caused, abnormal vibration may occur and thus the bearing or the body of the fluid machine may be damaged during the high-speed rotation of the shaft. This problem may arise not only in the configuration in which the impeller is fixed to the shaft at the entire length of the shaft bore, as described in JP-A-7-063193, but also in the configuration in which the impeller is fixed to the shaft at a part of the shaft bore, as described in JP-A-2004-060460, because of the fact that the fixing position of the impeller on the shaft (i.e., the position of the first engagement point) is difficult to specify.

[0006] In order to solve the above problem, it is known that, in the shrinkage fit process, the impeller and the shaft are securely bound or held by, e.g., a press machine, to prevent the relative positional deviation in the axial direction therebetween, until the impeller shrinks completely. Further, it is known that, for the sake of reducing a time spent for the complete shrinkage of the impeller, a cooling mechanism for an exclusive use is provided. However, these subsidiary apparatuses, such as the press machine, the cooling mechanism and the like, may result in increase in the manufacturing costs of the fluid machine.

SUMMARY OF THE INVENTION

[0007] It is an object of the present invention to provide a fluid machine including a shaft and an impeller, coupled to each other by an interference fit, wherein it is possible to surely prevent, by a simple structure, a relative positional deviation in an axial direction caused between the shaft and the impeller during a coupling work thereof, and thereby to ensure an inexpensive and high-performance configuration with an excellent safety and operational reliability.

[0008] To accomplish the above object, the present invention provides a fluid machine comprising a shaft; an impeller having a shaft bore into which the shaft is inserted, the impeller being coupled to the shaft by an interference fit; a positioning part provided between the shaft and the impeller, for positioning the impeller at a predetermined position on the shaft; a fitting part provided inside the shaft bore and adjacent to the positioning part, for forming the interference fit between the shaft and the impeller; and a loose-insertion part provided inside the shaft bore and adjacent to the fitting part, for forming a clearance between the shaft and the impeller.

[0009] In the above-described fluid machine, the positioning part may comprise a member separated from the shaft and the impeller.

[0010] Also, the positioning part may comprise a part of at least one of the shaft and the impeller.

[0011] Also, the fitting part and the loose-insertion part may be formed by varying, along an axial lengthwise direction, at least one of an outer diameter of the shaft and an inner diameter of the shaft bore of the impeller.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The above and other objects, features and advantages of the present invention will become more apparent from the following description of preferred embodiments in connection with the accompanying drawings, wherein:

Fig. 1 is a sectional view showing a shaft and an impeller of a fluid machine according to an embodiment of the present invention;

Fig. 2 is a sectional view showing a modification of the fluid machine of Fig. 1;

Fig. 3 is a sectional view showing another modification of the fluid machine of Fig. 1;

Fig. 4 is a sectional view showing a further modification of the fluid machine of Fig. 1; and

Fig. 5 is a sectional view showing an yet further modification of the fluid machine of Fig. 1.

DETAILED DESCRIPTION

[0013] The embodiments of the present invention are described below, and in detail, with reference to the accompanying drawings. In the drawings, the same or similar components are denoted by common reference numerals.

[0014] Referring to the drawings, Fig. 1 shows a shaft 12 and an impeller 14 of a fluid machine 10 according to an embodiment of the present invention. The fluid machine 10 according to the illustrated embodiment is configured as a centrifugal blower, and a known blade structure of the impeller 14 and a known structure of a housing (not shown) can be used for the fluid machine 10, the descriptions of which are thus omitted. It should be noted that the present invention can be applied not only to the centrifugal blower but also to other various fluid machines.

[0015] The fluid machine 10 includes a shaft 12 and an impeller 14 having a shaft bore 16 into which the shaft 12 is inserted, and is configured so that the impeller 14 is coupled to the shaft 12 through an interference fit. The fluid machine 10 further includes a positioning part 18 provided between the shaft 12 and the impeller 14, for positioning the impeller 14 at a predetermined position on the shaft 12; a fitting part 20 provided inside the shaft bore 16 and adjacent to the positioning part 18, for forming the interference fit between the shaft 12 and the impeller 14; and a loose-insertion part 22 provided inside the shaft bore 16 and adjacent to the fitting part 20, for forming a clearance between the shaft 12 and the impeller 14.

[0016] The shaft 12 is provided with a stepped cylindrical outer circumferential surface 12a extending along the rotation axis A of the shaft 12 and impeller 14 with the outer diameter of the outer circumferential surface 12a varying in a stepped manner. The impeller 14 is coaxially fixed to the outer circumferential surface 12a of

the impeller 14 at the predetermined axial position of the outer circumferential surface 12a. The shaft bore 16 of the impeller 14 has a cylindrical inner circumferential surface 16a extending along the rotation axis A of the shaft 12 and the impeller 14 with the inner diameter of the inner circumferential surface 16a being kept constant. The shaft 12, to which the impeller 14 is fixed, is rotatably supported by the housing (not shown) through a bearing 24 attached to the shaft 12 at its predetermined axial position. A shaft seal 26 is securely mounted to the shaft 12 at a predetermined axial position between the impeller 14 and the bearing 24.

[0017] The outer circumferential surface 12a of the shaft 12 includes a cylindrical large-diameter portion 28, on which the bearing 24 and the shaft seal 26 are mounted; a cylindrical intermediate-diameter portion 30 disposed axially adjacent to the large-diameter portion 28, the diameter of which is slightly reduced in comparison with the large-diameter portion 28 through a first annular-shoulder surface 12b generally orthogonal to the rotation axis A; and a cylindrical small-diameter portion 32 disposed axially adjacent to the intermediate-diameter portion 30, the diameter of which is slightly reduced in comparison with the intermediate-diameter portion 30 through a second annular-shoulder surface 12c generally orthogonal to the rotation axis A. The shaft seal 26 includes a cylindrical base 34 adapted to be fitted to the large-diameter portion 28 of the shaft 12. The base 34 of the shaft seal 26 is disposed to be aligned, at one axial end (an upper end, in the drawing) thereof, with the first annular-shoulder surface 12b of the shaft 12, and is disposed to be adjacent, at the other end (a lower end, in the drawing) thereof, to the bearing 24. The impeller 14 is fixed to the intermediate-diameter portion 30 of the shaft 12 at a first region 36 of the inner circumferential surface 16a of the shaft bore 16, which extends over a predetermined length from one axial end (a lower end, in the drawing) of the inner circumferential surface 16a. A remaining region (or a second region) 38 of the inner circumferential surface 16a of the shaft bore 16 of the impeller 14 is disposed so as not to contact the small-diameter portion 32 of the shaft 12.

[0018] In the illustrated embodiment, the positioning part 18 is configured from the first annular-shoulder surface 12b of the shaft 12 and the base 34 of the shaft seal 26, the base 34 being a member separated from both of the shaft 12 and the impeller 14. The impeller 14 receives the small-diameter portion 32 and the intermediate-diameter portion 30 of the shaft 12 successively in this order from one axial end (a lower end, in the drawing) of the shaft bore 16, and is abutted, at an annular area 14a of an axial end face adjacent to an opening at one axial end of the shaft bore 16, against both of the first annular-shoulder surface 12b of the shaft 12 and one axial end face (an upper end face, in the drawing) of the base 34 of the shaft seal 26. In this state, the impeller 14 is accurately located at the predetermined axial position on the shaft 12.

[0019] Further, in the illustrated embodiment, the fitting part 20 is configured by the cooperation between the intermediate-diameter portion 30 of the outer circumferential surface 12a of the shaft 12 and the first region 36 of the inner circumferential surface 16a of the shaft bore 16. The interference-fit configuration in the fitting part 20 can be surely obtained by at least one (or both) of processes of "a shrinkage fit" in which the impeller 14 is heated to be attached to the shaft 12 and "an expansion or cooling fit" in which the shaft 12 is cooled to be attached to the impeller 14. The outer diameter of the intermediate-diameter portion 30 of the shaft 12 and the inner diameter of the first region 36 of the shaft bore 16 are determined so as to ensure an interference sufficient to achieve an interference-fit structure having a desired strength. Also, the axial length of the intermediate-diameter portion 30 of the shaft 12 is determined so as to be sufficient to eliminate an inclination of the axis of the impeller 14 relative to the shaft 12. Still further, in the illustrated embodiment, the loose-insertion part 22 is configured by the cooperation between the small-diameter portion 32 of the outer circumferential surface 12a of the shaft 12 and the second region 38 of the inner circumferential surface 16a of the shaft bore 16.

[0020] In the fluid machine 10 configured as described above, when the shaft 12 is fixed to the impeller 14 by at least one of the shrinkage fit process and the expansion fit process, the small-diameter portion 32 and the intermediate-diameter portion 30 of the shaft 12 are first inserted successively in this order into the shaft bore 16 of the impeller 14, and the annular area 14a of the axial end face of the impeller 14 is brought into abutment with the positioning part 18 (i.e., the first annular-shoulder surface 12b of the shaft 12 and the base 34 of the shaft seal 26), whereby it is possible to accurately locate the impeller 14 at the predetermined axial position on the shaft 12. Then, the shaft 12 and the impeller 14 are left standing in this state, so that the impeller 14 as heated can shrink in the case of the shrinkage fit, or alternatively the shaft 12 as cooled can expand in the case of the expansion fit, and thereby the shaft 12 and the impeller 14 are engaged with each other first in the fitting part 20 (i.e., the intermediate-diameter portion 30 of the shaft 12 and the first region 36 of the shaft bore 16). During this step, due to the weight of the impeller 14 or a slight external force, the state where the annular area 14a of the impeller 14 abuts against the positioning part 18 can be easily maintained and, therefore, the shaft 12 and the impeller 14 are engaged with each other first at a certain point in the fitting part 20 in the state where the impeller 14 is surely located at the predetermined axial position on the shaft 12.

[0021] Thereafter, heat is exchanged between the shaft 12 and the impeller 14 that are in contact with each other and, thereby, the expansion of the shaft 12 and the shrinkage of the impeller 14 are substantially simultaneously performed, so that the interference fit in the fitting part 20 is completed. The subsequent expansion of the

shaft 12 and the subsequent shrinkage of the impeller 14, after the completion of the interference fit, advance in directions reverse to each other, as shown by arrows in Fig. 1. Such thermal deformations of both the shaft 12 and the impeller 14 in the reverse directions can be smoothly performed, due to the provision of the loose-insertion part 22 (i.e., the small-diameter portion 32 of the shaft 12 and the second region 38 of the shaft bore 16). Then, at an instant when the thermal deformations of both the shaft 12 and the impeller 14 are finished, the operation for attaching the impeller 14 to the shaft 12 is completed. The impeller 14 thus attached to the shaft 12 possesses a significantly high positional accuracy in the axial direction.

[0022] As described above, in the fluid machine 10 in which the fitting part 20 is provided adjacent to the positioning part 18 inside the shaft bore 16, it is possible, when the shaft 12 is fixed to the impeller 14 by at least one of the processes of the shrinkage fit and the expansion fit, to easily and surely specify the fixing position of the impeller 14 on the shaft 12 (i.e., the position of the first engagement point) and thus to establish the interference fit in the fitting part 20. Further, the loose-insertion part 22 is provided adjacent to the fitting part 20 inside the shaft bore 16, so that it is possible to control the expansion of the shaft 12 and the shrink of the impeller 14, after the completion of the interference fit, in the predetermined directions. As a result, it is possible to surely prevent, by a simple structure, a relative positional deviation in an axial direction caused between the shaft 12 and the impeller 14 during the coupling work thereof, so as to improve the positional accuracy in the axial direction of the impeller 14 on the shaft 12, as well as of the other components attached to the shaft 12, such as the bearing 24, the shaft seal 26 and the like. Accordingly, the fluid machine 10 can ensure an inexpensive and high-performance configuration with an excellent safety and operational reliability.

[0023] It should be noted that, in the above-described configuration in which the interference fit between the shaft 12 and the impeller 14 is ensured by at least one of the processes of the shrinkage fit and the expansion fit, it is advantageous that the shaft 12 and the impeller 14 are made of materials having mutually different heat-shrinkage rates, in view of facilitating the effect of the interference fit.

[0024] In the fluid machine 10 described above, the positioning part 18 may also be configured by either one of the base 34 of the shaft seal 26 (i.e., a member separated from the shaft 12 and impeller 14) and the first annular-shoulder surface 12b of the shaft 12 (i.e., a part of the shaft 12). In the case where the positioning part 18 is configured by using a component provided for other purposes, such as the shaft seal 26 attached to the shaft 12 and adjacent to the impeller 14, it is possible to reduce the number of manufacturing steps and the number of components. On the other hand, in the case where the positioning part 18 is configured by a part of at least one

of the shaft 12 and the impeller 14, it is possible to maintain the stable positioning function.

[0025] Further, the fitting part 20 and the loose-insertion part 22 may be defined by varying, along an axial lengthwise direction, a diametral dimension of at least one of the outer circumferential surface 12a of the shaft 12 and the inner circumferential surface 16a of the shaft bore 16 of the impeller 14. According to this configuration, the fitting part 20 and the loose-insertion part 22 can be configured very simply and easily. Hereinafter, various modifications of the above-described fluid machine 10 will be described with reference to Figs. 2 to 5. The components shown in Figs. 2 to 5, corresponding to those of the fluid machine 10 in Fig. 1, are designated by common reference numerals, and the descriptions thereof are not repeated.

[0026] In a modification shown in Fig. 2, in place of the above-described intermediate-diameter portion 30, the shaft 12 is provided, at the outer circumferential surface 12a thereof, with a tapered portion 40 defined between the first annular-shoulder surface 12b and the small-diameter portion 32, the outer diameter of the tapered portion 40 being gradually reduced starting from the first annular-shoulder surface 12b up to the small-diameter portion 32. The tapered portion 40 is engaged, at a point adjacent to the first annular-shoulder surface 12b, with an end portion 36a of the above-described first region 36 in an interference-fit condition, the end portion 36a being adjacent to the opening end (the lower end, in the drawing) of the shaft bore 16 of the impeller 14, opening to the positioning part 18, and thereby the fitting part 20 is constituted. In this configuration, provided that a sufficient interference is obtained for the interference fit in the fitting part 20, it is possible to establish a fitting structure having a required strength, and also to eliminate the inclination of the axis of the impeller 14 relative to the shaft 12 by the function of the positioning part 18 (i.e., the first annular-shoulder surface 12b of the shaft 12 and the base 34 of the shaft seal 26). According to this configuration, characteristic effects, equivalent to those of the fluid machine 10 shown in Fig. 1, are also ensured.

[0027] In a modification shown in Fig. 3, the intermediate-diameter portion 30 and the second annular-shoulder surface 12c, as described above, are eliminated from the outer circumferential surface 12a of the shaft 12, so that the large-diameter portion 28 and the small-diameter portion 32 are adjacent to each other with the first annular-shoulder surface 12b arranged therebetween. On the other hand, the inner circumferential surface 16a of the shaft bore 16 of the impeller 14 is formed to have a stepped cylindrical shape including the above-described first region 36 defined by a small-diameter cylindrical surface and the above-described second region 38 defined by a cylindrical surface having a diameter larger than the first region 36. The first region 36 of the shaft bore 16 of the impeller 14 is engaged with a distal end area 42 of the small-diameter portion 32 of the shaft 12 in an interference-fit condition, the distal end area 42 being adja-

cent to the first annular-shoulder surface 12b, and thereby the fitting part 20 is constituted. In this configuration, provided that a sufficient interference and a sufficient axial length are obtained for the interference fit in the fitting part 20, it is possible to establish a fitting structure having a required strength, and also to eliminate the inclination of the axis of the impeller 14 relative to the shaft 12. According to this configuration, characteristic effects, equivalent to those of the fluid machine 10 shown in Fig. 1, are also ensured.

[0028] In a modification shown in Fig. 4, the outer circumferential surface 12a of the shaft 12 is formed so that the large-diameter portion 28 and the small-diameter portion 32 are adjacent to each other with the first annular-shoulder surface 12b arranged therebetween, in a manner similar to the configuration of Fig. 3. On the other hand, the shaft bore 16 of the impeller 14 is provided in the inner circumferential surface 16a thereof with the above-described second region 38 defined by a large-diameter cylindrical surface and a tapered region 44 defined between the second region 38 and the opening end (the lower end, in the drawing) opening to the positioning part 18, the inner diameter of the tapered region 44 being gradually reduced starting from the second region 38 up to the opening end. The tapered region 44 of the shaft bore 16 is engaged, at a point adjacent to the opening end opening to the positioning part 18, with an end portion 32a of the small-diameter portion 32 of the shaft 12 in an interference-fit condition, the end portion 32a being adjacent to the first annular-shoulder surface 12b, and thereby the fitting part 20 is constituted. In this configuration, provided that a sufficient interference is obtained for the interference fit in the fitting part 20, it is possible to establish a fitting structure having a required strength, and also to eliminate the inclination of the axis of the impeller 14 relative to the shaft 12 by the function of the positioning part 18 (i.e., the first annular-shoulder surface 12b of the shaft 12 and the base 34 of the shaft seal 26). According to this configuration, characteristic effects, equivalent to those of the fluid machine 10 shown in Fig. 1, are also ensured.

[0029] In a modification shown in Fig. 5, in place of the above-described positioning part 18 using the shaft seal 26, a positioning part 46 formed by parts of both the shaft 12 and the impeller 14 is provided inside the shaft bore 16 of the impeller 14. More specifically, the outer circumferential surface 12a of the shaft 12 is formed so that the large-diameter portion 28 and the small-diameter portion 32 are adjacent to each other with the first annular-shoulder surface 12b arranged therebetween, and that the large-diameter portion 28 is extended to protrude from the base 34 of the shaft seal 26 and inserted into the shaft bore 16 of the impeller 14. On the other hand, the inner circumferential surface 16a of the shaft bore 16 of the impeller 14 is formed to have a stepped cylindrical shape including the large-diameter first region 36 adjacent to the opening end (the lower end, in the drawing) opening to the shaft seal 26, the large-diameter second

region 38 adjacent to the opposite opening end, and a small-diameter third region 48 defined between the first region 36 and the second region 38. Also, in the shaft bore 16 of the impeller 14, an annular-shoulder surface 16b substantially orthogonal to the axis A is formed between the first region 36 and the third region 48. The annular-shoulder surface 16b of the shaft bore 16 of the impeller 14 cooperates with the first annular-shoulder surface 12b of the shaft 12 and, thereby, the positioning part 46 is constituted. Further, the third region 48 of the shaft bore 16 of the impeller 14 is engaged with a distal end area 50 of the small-diameter portion 32 of the shaft 12 in an interference-fit condition, the distal end area 42 being adjacent to the first annular-shoulder surface 12b and, thereby, the fitting part 20 is constituted.

[0030] In the above configuration, when the shaft 12 is fixed to the impeller 14 by at least one of the shrinkage fit process and the expansion fit process, the small-diameter portion 32 and the large-diameter portion 28 of the shaft 12 are first inserted successively in this order into the shaft bore 16 of the impeller 14, and the first annular-shoulder surface 12b of the shaft 12 is brought into abutment with the annular-shoulder surface 16b of the shaft bore 16 of the impeller 14, whereby it is possible to accurately locate the impeller 14 at the predetermined axial position on the shaft 12 by the function of the positioning part 46. In this state, the interference fit is completed in the fitting part 20 (i.e., the distal end area 50 of the small-diameter portion 32 of the shaft 12 and the third region 48 of the shaft bore 16), so that it is possible to attach the impeller 14 to the shaft 12 in the state where the impeller 14 is accurately located at the predetermined axial position on the shaft 12. During a period when heat is exchanged between the shaft 12 and the impeller 14, that are in contact with each other at the fitting part 20, the thermal deformations of the shaft 12 and the impeller 14 advance in the directions shown by arrows in Fig. 5. According to this configuration, as the positioning part 46 and the fitting part 20 are provided adjacent to each other inside the shaft bore 16, it is also possible to easily and surely specify the fixing position of the impeller 14 on the shaft 12 (i.e., the position of the first engagement point) and thus to establish the interference fit in the fitting part 20. As a result, characteristic effects, equivalent to those of the fluid machine 10 shown in Fig. 1, are also ensured.

[0031] While the invention has been described with reference to specific preferred embodiments, it will be understood, by those skilled in the art, that various changes and modifications may be made thereto without departing from the scope of the following claims.

Claims

1. A fluid machine comprising a shaft (12) and an impeller (14), said impeller having a shaft bore (16) into which said shaft is inserted, and said impeller being coupled to said shaft by an interference fit, **charac-**

terized in that said fluid machine comprises:

a positioning part (18) provided between said shaft and said impeller, for positioning said impeller at a predetermined position on said shaft; a fitting part (20) provided inside said shaft bore and adjacent to said positioning part, for forming said interference fit between said shaft and said impeller; and a loose-insertion part (22) provided inside said shaft bore and adjacent to said fitting part, for forming a clearance between said shaft and said impeller.

2. A fluid machine as set forth in claim 1, wherein said positioning part comprises a member (34) separated from said shaft and said impeller.
3. A fluid machine as set forth in claim 1, wherein said positioning part comprises a part (12b) of at least one of said shaft and said impeller.
4. A fluid machine as set forth in any one of claims 1 to 3, wherein said fitting part and said loose-insertion part are formed by varying, along an axial lengthwise direction, at least one of an outer diameter of said shaft and an inner diameter of said shaft bore of said impeller.

Fig.1

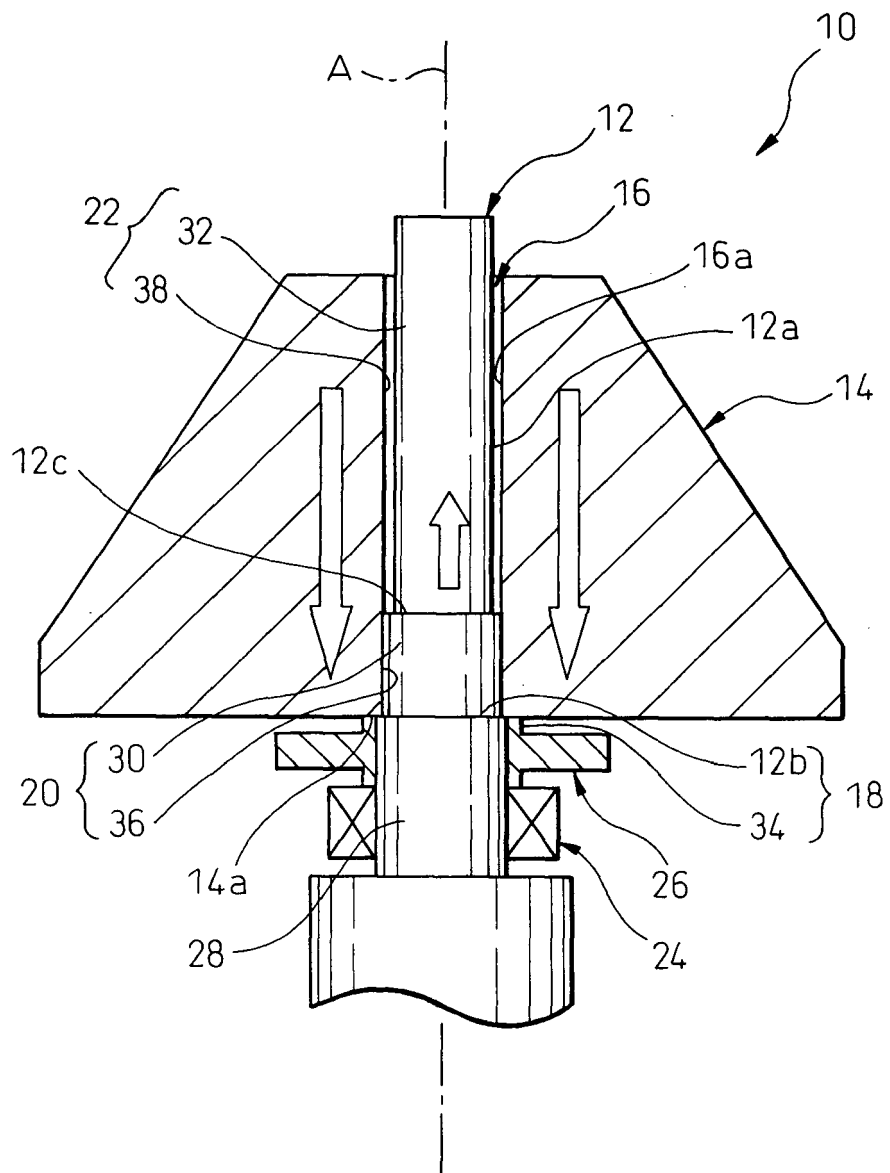


Fig.2

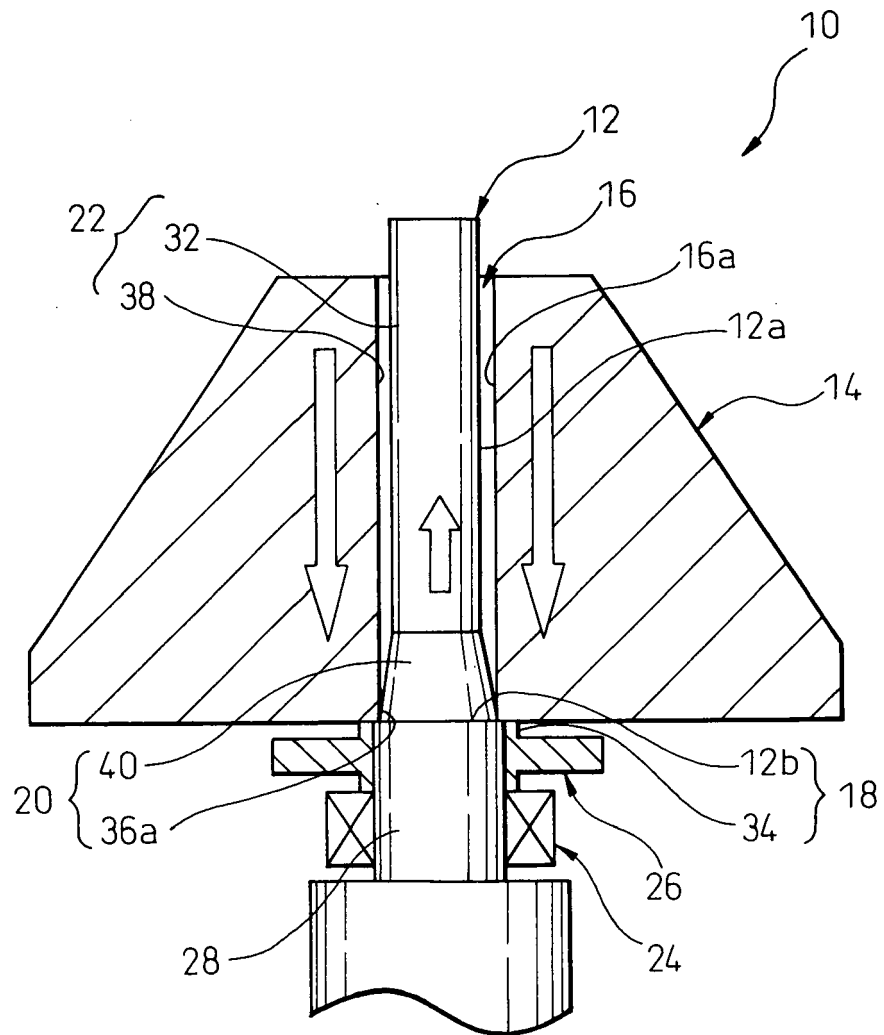


Fig.3

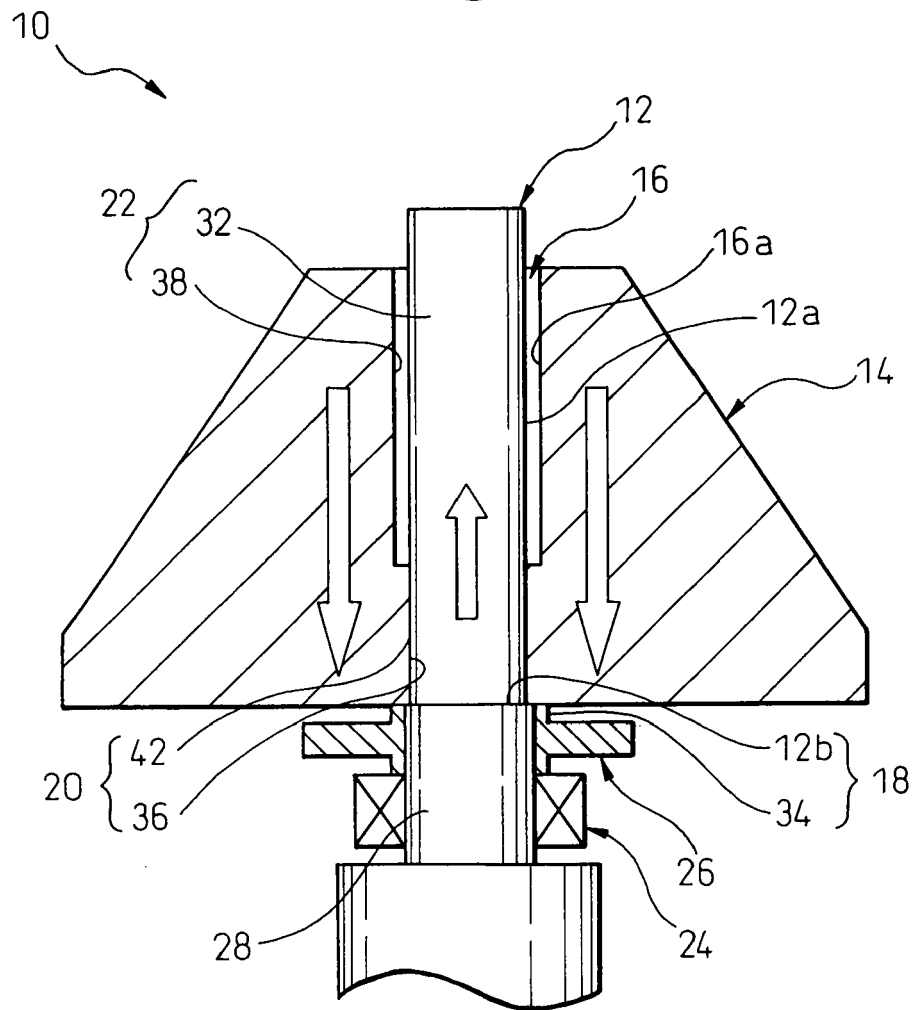


Fig.4

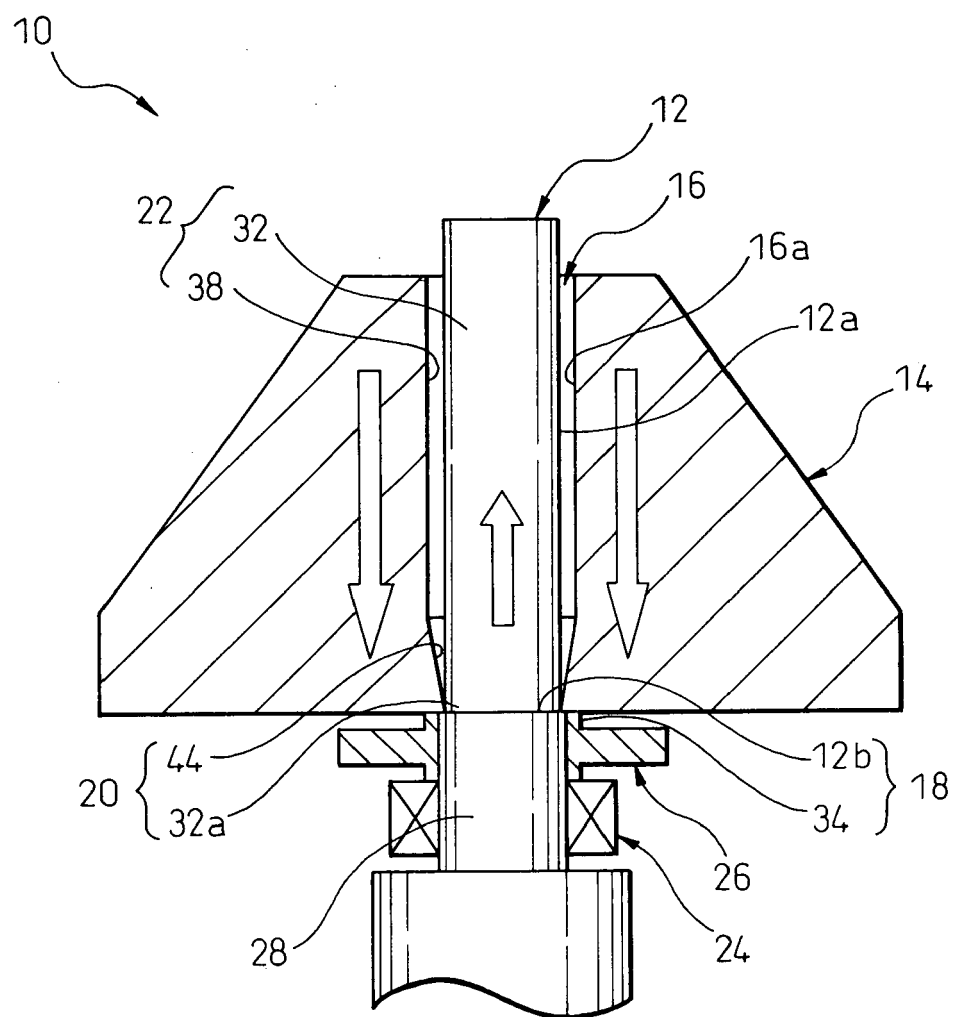
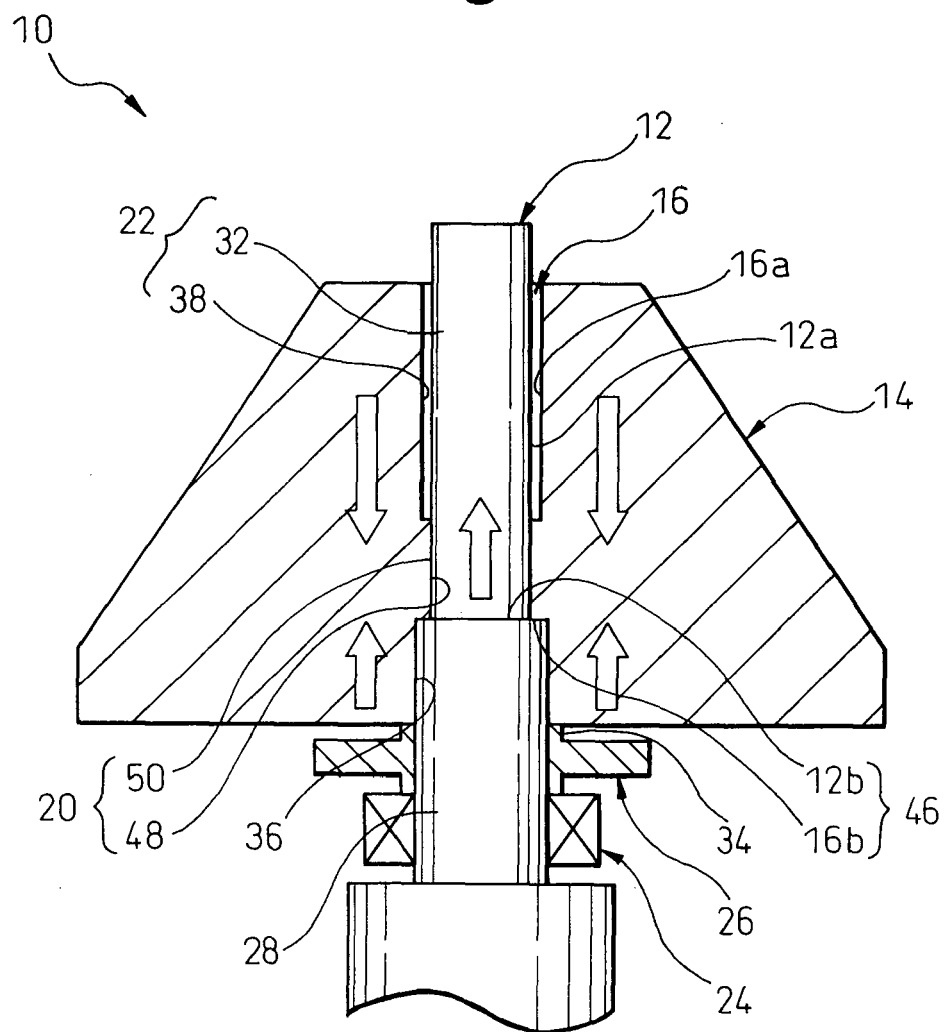


Fig.5



REFERENCES CITED IN THE DESCRIPTION

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