CENTRIFUGAL PUMP MODULAR
BEARING SUPPORT FOR PUMPING
FLUIDS CONTAINING ABRASIVE
PARTICLES

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U.S. Cl. ........................................... 415/170.1; 415/180;
415/172.1; 415/901; 384/425
Field of Search .......................... 415/104, 105, 106, 107,
415/113, 112, 170 R, 170 A, 172 R, 501, 199.1,
199.2, 199.3; 384/425, 426

References Cited
U.S. PATENT DOCUMENTS
2,775,945 1/1957 Arutunoff ............... 415/172
2,918,975 12/1959 Conery et al. .......... 415/199.4
3,238,879 3/1966 Shallenberger .......... 415/199.4
3,457,045 4/1969 Tremain ............... 415/214
3,716,309 2/1973 Mitchell ................ 417/422
3,960,468 6/1976 Boorse et al. ........... 415/104 X

Primary Examiner—Robert E. Garrett
Assistant Examiner—Joseph M. Pitko

ABSTRACT
A submersible centrifugal pump is disclosed. It includes a housing with a linear stack of axially mounted pumping units therein. Each unit constructed as a module with at least a first and a second impeller mounted to a central shaft. A diffuser forms an outer casing which is provided for each impeller. A thrust bearing, lubricated and cooled by the fluid being pumped is supported from and to the outer casing and is arranged to receive axial force from the upstream impellers in each modular unit. A plurality of impellers and diffusers can form a single modular unit.

16 Claims, 8 Drawing Sheets
CENTRIFUGAL PUMP MODULAR BEARING
SUPPORT FOR PUMPING FLUIDS CONTAINING
ABRASIVE PARTICLES

DISCLOSURE STATEMENT

A preliminary patentability search revealed the fol-

lowing U.S. Patents:

2,918,975 Conery et al
3,238,879 Shallenbarg
3,437,045 Tremain
3,716,309 Mitchell
4,120,606 Reese
4,172,690 Kuniz
4,323,524 Smith
4,511,307 Drake

These patents all relate to some type of pump for
pumping fluids. For example, the Conery et al patent
shows a multi-stage pump. The Shallenbarg patent
discusses a submersible pump having a plurality of linearly
stacked pumping units. The Tremain patent relates to a
plurality of stacked plastic cases. The Mitchell patent is
a submersible motor and pump unit. The Reese patent is
directed to the concept of improved ways for connect-
ing the end portions of the pump housing and its adja-
cent components. The Smith patent shows a single
sleeve bearing 54. The Kuniz patent is for arrangement
for centering the impellers in a multi-stage centrifugal
pump. The Smith patent shows a sleeve bearing and
filter for reducing the wear on a submersible electric
pump. The Drake patent includes a rotatable impeller
and fixed diffuser and has a bearing that is constructed
from a hardness greater than the hardness of sand.

FIELD OF THE INVENTION

This present invention relates to a multi-stage centri-
fugal pump with special modular construction and a
special bearing for absorbing the thrust generated by the
impeller stages in each module.

BACKGROUND OF THE INVENTION

Multi-stage centrifugal pumps are well known in the
art and are generally comprised of a number of impel-

lers which impart pressure and kinetic energy to a fluid
which is being pumped and also includes a diffuser be-

tween impellers which guide the fluid to and from the
impellers. An impeller and a diffuser comprises one
“stage”. Rotation of the impellers causes fluid to be
pumped in one direction, e.g., upwardly and as it is
pumped it develops a pressure differential which tends
to force the impellers in a reverse direction, e.g. down-
ward which is called “down thrust”. These centrifugal
pumps are widely used for submersible pumping of fluid
from a well bore and in which the housing of the centri-
fugal pumps are cylindrical and are placed in a verti-
cal position with the fluid entering the bottom of the
pump and going out the top. This “down thrust” is
absorbed by bearings, located either externally or
within each diffuser of the pump.

In one embodiment in order to transfer the thrust to an
external bearing, the impellers are fixed axially to the
shaft. This is commonly known as a “fixed impeller”
pump. If the generated thrust is to be absorbed by a 65
bearing in the stage itself, the impellers are not fixed
axially to the shaft in order that each impeller may run
on its individual thrust bearing. This type is commonly

known as a “floating impeller pump”. When pumping
fluids from great depths, i.e., deep wells or against higher
pressures, the “fixed impeller” pumps are at a

disadvantage because of the limitation of the amount of
thrust which can be transmitted down the shaft, or by
the thrust capacity of the external bearing. When pump-
ing fluids containing abrasive particles, such as sand, the
“floating impeller” pumps are at a disadvantage because of
the bearing wear due to these particles in the fluid. In

situations where the pumps must deliver fluids contain-
ing abrasive particles from great depths, such as sub-
mersible oil field pumps, the pumps traditionally suffer
extremely short lives. The use of bearing materials
which are significantly harder than the abrasive in the

“floating impeller” pumps have increased the pump life,
but at an expense that is seldom justified.

It is therefore an object of the present invention to
describe a multi-stage centrifugal pump having a novel
means of transferring the down thrust from a plurality
of impellers to a special bearing that is designed to oper-
ate in and be lubricated by the fluid being pumped.

SUMMARY OF THE INVENTION

The present invention provides a multi-stage centri-
fugal pump with a modular thrust bearing which absorbs
all of the thrust generated by the impellers in that mod-
ule. The maximum pump pressure is therefore not lim-
ited by the thrust. The thrust bearing is lubricated by
the fluid being pumped.

The centrifugal pump is made up of a plurality of
axially aligned modules with each module having a fluid
conveying passageway and an axial bore. A shaft ex-
tends through the bores and the pump impellers are
attached so that the rotation of the shaft is transmitted
to the impellers. Each module has a plurality of impel-

lers and mating diffusers which when fitted together form
a casing. Each impeller has a hub and they are so ar-
anged so that the thrust developed by one of the impel-

lers is transmitted to the hub of the impeller immedi-
ately below it and finally to the modular thrust bearing
to receive the thrust for all the impellers in that particu-
lar module.

The modular thrust bearing has a rotating member
which is rotatably supported by the shaft. The rotating
bearing surface contacts a fixed stationary bearing
member which is supported from and to the casing
formed by the diffusers and provides an annular cavity
for fluid passage and transferring the thrust developed
by the impellers of the module to the casing. Several
different designs of the thrust bearing are disclosed. The
modules, which may be a plurality, are retained within
a pump housing.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view of a prior art “fixed impel-

ler” pump.

FIG. 2 is a sectional view of a prior art “floating

impeller” pump.

FIG. 3 is a sectional view of a portion of a multi-stage
centrifugal pump embodying the present invention.

FIG. 4A is an exploded view showing the rotating
thrust disc and the flat stationary thrust bearing of the

bearing assembly.

FIG. 4B is a full face view of the bearing surface of
the rotating thrust disc of FIG. 4A.

FIG. 4C is a full face view of the stationary thrust
bearing of FIG. 4A.
FIG. 5 is similar to FIG. 4A except that the stationary thrust bearing is provided with lubricating grooves.

FIG. 6 is similar to FIG. 5 showing modified lubricating grooves in the stationary thrust bearing surface.

FIG. 7 is a sectional view showing a modified rotating thrust disc and the stationary thrust bearing assembly.

FIG. 8 is a sectional view of a modified bearing assembly.

FIG. 9 is a full face view of a modified stationary thrust bearing.

FIG. 10 is a sectional view of another embodiment of a thrust bearing assembly.

**DETAILED DESCRIPTION**

It is considered that a brief review of the prior art showing a “fixed impeller” and a “floating impeller” type centrifugal pump will be helpful in understanding improvements provided by the present invention. In this regard attention is first directed to FIG. 1 which shows a prior art “fixed impeller” type multi-stage centrifugal pump which is generally identified by the reference character 10. The pump 10 includes an outer housing 12 having diffusers 14 which are constructed to provide a circuitous passageway as shown by arrows 18 from the outer periphery 20 of adjacent rotating impellers 16 to the inner periphery or eye 22 of the next impeller. One impeller and one diffuser form one pump stage. Each diffuser is formed of an inner bore 24 through which each impeller axially extends. The outer portion of each diffuser forms an outer casing 28 which are retained together in compression by upper and lower threaded sleeves 30. Grooves 32 and O-rings therein provide a seal with housing 12. A shaft 26 extends through the bore 24. The impellers 16 are each fixed to the shaft 26, e.g., by a keyway, not shown, with an inner hub 17, and are spaced between diffusers 14. When the shaft 26 rotates it rotates the impellers 16 therewith. Fluid is drawn upward and forced through the circuitous fluid passageways as shown by the arrows 18. In order to increase the head or pressure produced a large number of stages may be stacked on each other as shown in FIG. 1.

As can be seen in FIG. 1 the hubs 17 of the impellers seat against each other in order that the thrust generated is transferred down the impeller stack through the hubs until it reaches thrust retaining ring 34 which is secured to shaft 26 where the thrust is thus transferred to the shaft. The thrust is finally absorbed in a sealed lubricating thrust bearing, not shown, below the pump.

FIG. 2 represents the prior art showing a “floating impeller” pump generally designed at 38 in a housing 39. Shown thereon are impellers 40 which are keyed to shaft 42 yet capable of relative vertical movement thereto. As in the “fixed impeller” type each impeller 40 is rotatably positioned relative to and between stationary diffusers 44 creating a circuitous passageway for the fluid being pumped as shown by arrowed lines 46. As previously described in FIG. 1, the diffusers are retained in a housing 39 by threaded upper (and lower) retainers 48, the outer casing 49 of each being sealed at grooves 51 by O-rings. The actual pumping operation is similar to that of the device of FIG. 1 in that the fluid being pumped is drawn up through the circuitous fluid passageway 46 in the impellers and diffusers. However, in the embodiment of FIG. 2 the hubs 50 of the impellers 40 are slightly separated from each other by a space 52. Thus, none of the thrust generated by the pumping of the fluid is transferred to the shaft 42. Each impeller 40 is provided with lower down-thrust washers or bushings 54 and 56 and up-thrust washers and bushings 58, which rotate relative to adjacent surfaces on the diffuser. As each impeller 40 is rotated a pressure differential develops between the outlet and the inlet which tends to drive the impeller 40 downwardly. This action, combined with abrasive laden fluids, prematurely wears out the down-thrust washers or bushings 54 and 56. Forming the washers of exotic or hardened materials as in the prior art (See U.S. Pat. No. 4,511,307) does not necessarily provide a satisfactory solution.

Attention is next directed to FIG. 3 which shows a preferred embodiment of the invention. Reference numeral 60 generally indicates a multi-stage centrifugal pump within a housing 61. Depending upon the design pressure required, the pump is comprised of one or more modules 62. Each module 62 will include one or more pump stages formed by a diffuser 64 and an impeller 66, the latter of which is attached to rotary shaft 67. The diffusers 64 are formed with nestable outer casings 68 which are retained in housing 61 as shown in the prior art. Similarly the combination of rotary impellers 66 and diffusers 64 create the circuitous flow passage 70 for the fluid being pumped similar to that shown in FIGS. 1 and 2. Each impeller 66 is provided with a plurality of lower down-thrust bushings 72 and 74 and up-thrust bushings 76. As the impeller 66 is rotated, a pressure differential develops between a high pressure side 78 and a low pressure side 80 of the impeller 66 which tends to drive the impeller 66 and thereby prematurely wearing out the lower down-thrust bushings 72 and 74. The embodiment of the present invention illustrated in FIG. 1 provides a novel means to absorb “down thrust” and prevent the premature failure of the bushing and seal surfaces.

Each impeller 66 has a hub 82 which is keyed to the shaft 67 as a floating impeller, i.e., capable of vertical movement. The hubs 82, once the down-thrust force has ‘worn in’ the bushings or washers 72 and 74, will transmit the down-thrust from hub-to-hub to a hub of a thrust disc 84 which surrounds pusher shaft 67 and is rotatable therewith. Like the impellers 66, hub 83 can move longitudinally with respect to shaft 67. Thus, the thrust disc 84 rotates with the shaft 67 and transmits the thrust and rotation to a thrust bearing surface 86 which is fixed to thrust disc 84. The rotating thrust bearing surface 86 runs against the stationary thrust bearing surface 88 which is lubricated and cooled by the fluid being pumped and supported by a bushing carrier 90. Annular cavities 92 in the bearing carrier 90 allow for the passage of fluid from either the pump suction, or as shown, from the outlet of the topmost impeller 66 in the module below. An elastomeric radial bearing member 93 which contacts sleeve 94 provides radial support for the pump shaft. If desired the radial bearing 93 could be in direct contact with the shaft 67. Because the thrust bushing carrier 90 is assembled as part of the nested outer casings 68 of diffusers 64, the resultant down-thrust is transferred to those casings.

Although the ability of the modular bearing described above in regard to FIG. 3 to function as described above does not rely upon a specific configuration of the module thrust bearing there are some configurations of the bearing that, for a particular operating environment, will have a greater useful operation life than others. FIGS. 4A through 10A show some of these
configurations, and like numerals are used where like parts are previously described.

FIGS. 4A, 4B AND 4C show perhaps the simplest form of the thrust bearing. This includes a rotating thrust disc 84 and its bearing surface 86. It also includes a flat stationary thrust bearing surface 88 and its carrier 90. In use as the bearing surfaces are lapped flat, this configuration tends to limit the entrance of abrasive particles into the bearing area because of the extremely thin layer of lubricating fluid between bearings 86 and 88. This particular configuration of FIG. 4A does have limitations because it can require greater torque than some of the configurations discussed hereinafter because of limitation in lubrication inherent in flat thrust bearings. Because of this the bearing is limited to low loads.

FIG. 5 is similar to the bearing of FIG. 4A except for the provision of lubricating grooves 102 in the face 104 of carrier 90 from the outer periphery 105 to the inner periphery 107. These grooves provide the means for better lubrication allowing the bearings to run cooler and carry greater loads than the flat faced bearings of FIG. 4. It should be noted that the bearing will have similar functions if the groove face is a part of the rotary thrust bearing surface 86 or if both bearing surfaces have grooves.

FIG. 6 shows a stationary thrust bearing 106 with lubricating grooves 108 which is held in carrier 90. In this embodiment the grooves 108 do not extend all the way across the bearing surface to the inner periphery 110. A major advantage is that the partial groove act as seals to exclude the abrasive particles from the bearing surface.

Attention is next directed to FIG. 7 which shows an alternate embodiment of a partial groove stationary bearing having lubrication grooves 112. A seal ring 114 is located at the inside diameter or periphery of the stationary bearing surface 116. An elastomeric spring 118 restricts the thrust force transferred from the carrier 90 to the sealing ring 114. Seal ring 114 runs against the flat face 120 of the rotating bearing 122 thus preventing abrasives from entering the bearing area. Similarly as with the other embodiments discussed above the rotating and stationary elements of the bearing seal arrangement may be interchanged.

FIG. 8 shows still another embodiment of the thrust bearing assembly. Shown thereon is a rotating thrust disc 130 with its bearing 132 and a stationary thrust bearing 134 with lubricating grooves 136 in its carrier 138. Abrasive evacuation holes 140 are provided in the rotating thrust disc 130. When rotating thrust disc 130 rotates these evacuation holes 140 act as small centrifugal pumps circulating the fluid and removing the abrasive particles from the inside of the bearing. This prevents these particles from collecting and causing damage and wear disproportionate to their actual concentration in the pump fluid.

Another embodiment of the thrust bearing assembly is shown in FIGURE 9. A stationary thrust bearing surface 150 is shown with angular spaced lubricating grooves 152 and its carrier 154. Grooves 152 function similar to the grooves shown in FIG. 5. Grooves 152 are tangential to the periphery of the bore 156 which generally extend into the direction of rotation 158 of the rotating thrust disc, not shown in this view. These grooves thus offer no corners in the direction of rotation for the abrasive material to erode. As these grooves extend inwardly from the outside and generally the direction of rotation abrasive particles in the lubricating grooves tend to be carried to the inside of the thrust bearing where they can be removed by evacuation holes such as shown in FIG. 8.

Attention is next directed to FIG. 10. This assembly is another embodiment where a rotating thrust disc 160 is formed with a downward hub 162 about shaft 67 which is radially supported by bearing 164. Disc 166 is supported to the disc 160 while disc 168 is supported by the carrier 170 as shown in FIG. 10.

The particular thrust bearing assembly can be selected by a skilled designed of the centrifugal pumps such as described above so that the most efficient thrust bearing will be selected as may be needed for the particular fluid being pumped. This would take into account the abrasive particles contained in the fluid, pressures to the developed and the rate of flow.

While the invention has been described with a certain degree of particularity, it is manifest that many changes may be made in the details of construction and the arrangement of components without departing from the spirit and scope of this disclosure. It is understood that the invention is not limited to the embodiments set forth herein for purposes of exemplification, but is to be limited only by the scope of the attached claim or claims, including the full range of equivalency to which each element thereof is entitled.

What is claimed is:
1. A submersible pump for pumping fluids which may contain abrasives which comprises:
   a plurality of vertically oriented diffusers which form an outer casing;
   a longitudinal shaft rotatably mounted through the center of said diffusers;
   an impeller for each said diffuser, each impeller having a hub supported by said shaft and axially moveable thereon, the bottom of each hub of each impeller capable of abutment with the top of the next lower impeller hub to transfer down thrust to said next impeller hub, a thrust bearing assembly positioned about said shaft, said assembly having a thrust plate rotatably supported to said shaft for receiving said down thrust from the bottommost of said hubs; and
   a stationary thrust bearing in contact with said thrust plate, said thrust bearing supported to said outer casing of said diffuser whereby said down thrust is transferred to said outer casing.
2. The pump of claim 1 wherein each impeller has at least one downthrust washer for contact with said diffuser.
3. The pump of claim 1 including a separate housing and wherein said outer casings of said diffusers are affixed within said housing.
4. A pump as defined in claim 1 in which said thrust plate of said thrust bearing assembly includes a cylindrical sleeve surrounding and rotatably attached to said shaft; and wherein said stationary thrust bearing has a flat circular face for contact with said thrust plate, said bearing and said circular face having an outer periphery and an inner bore for said shaft, said circular face having lubricating grooves therein.
5. The pump of claim 4 wherein said grooves extend radially.
6. The pump of claim 4 wherein said grooves extend partially radially from said outer periphery.
7. The pump of claim 4 wherein said grooves are angularly oriented so as to be tangential with said inner
bore and oriented in a direction opposite that of said rotating thrust bearing.

8. The pump of claim 4 including a plurality of evacuating holes extending through said thrust plate and thrust bearing which slant outwardly from a position adjacent said shaft.

9. A submersible pump for pumping fluids comprising a plurality of vertically oriented pumping modules, each said module comprising a plurality of diffusers which form an outer casing; a rotatable longitudinal shaft mounted in the center of each said diffuser; an impeller cooperating with each said diffuser, each said impeller having a hub portion rotatably supported by said shaft and axially movable thereon; a thrust bearing assembly positioned about said shaft below the bottommost hub portion, said thrust bearing assembly having a thrust plate rotatably supported to said shaft, said thrust plate capable of abutment with the bottom of said hub portion to receive down thrust therefrom during operation; and a stationary thrust bearing in contact with said thrust plate, said thrust plate supported to and formed as a part of said outer casing of said diffuser whereby said down thrust from each module is transferred to said outer casing.

10. The pump of claim 9 including a separate housing and wherein said outer casings of said diffusers are affixed within said housing.

11. The pump of claim 9 wherein each impeller has at least one down thrust washer for contact with said diffuser.

12. A pump as defined in claim 9 in which said thrust plate of said thrust bearing assembly includes a cylindrical sleeve surrounding and rotatably attached to said shaft; and wherein said stationary thrust bearing has a flat circular face for contact with said thrust plate, said bearing and said circular face having an outer periphery and an inner bore for said shaft, said circular face having lubricating grooves therein.

13. The pump of claim 12 wherein said grooves extend radially.

14. The pump of claim 12 wherein said grooves extend partially radially from outer periphery.

15. The pump of claim 12 wherein said grooves are angularly oriented so as to be tangential with said inner bore and oriented in a direction opposite that of said rotating thrust bearing.

16. The pump of claim 12 including a plurality of evacuating holes extending through said thrust plate and thrust bearing which slant outwardly from a position adjacent said shaft.
UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 4,872,808
DATED : 10/10/89
INVENTOR(S) : Brown L. Wilson

It is certified that error appears in the above—identified patent and that said Letters Patent is hereby corrected as shown below:

Claim 9, column 7, line 23, change "thrust plate," second occurrence, to --stationary thrust bearing--

Signed and Sealed this
Twenty-ninth Day of December, 1992

Attest:

DOUGLAS B. COMER
Attestting Officer
Acting Commissioner of Patents and Trademarks