An integral motor and pump includes a casing having an inlet and an outlet, and a motor mounted within the casing. The motor includes a rotor member and a stator member. A tubular shaft circumscribing a central axis is received and fixed within the rotor. The tubular shaft is formed from a pair of axially overlapping tubular end portions and has an inner peripheral wall. An impeller is longitudinally spaced and press-fit within the inner peripheral wall of the shaft. The impeller includes a central, axially-extending body and a series of radially projecting blades, with each blade extending radially outward from the central body to the inner peripheral wall. When the motor is energized, the rotor turns, which in turn causes the impeller to rotate and draw fuel through the pump. When the motor is off, a flow path is maintained through the pump between the blades of the impeller.
PUMP WITH INTEGRAL MOTOR AND IMPELLER

CROSS-REFERENCE TO RELATED CASES

[0001] The present application claims the benefit of the filing date of U.S. Provisional Application Serial No. 60/339,377; filed Dec. 10, 2001, the disclosure of which is expressly incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to centrifugal fuel pumps, such as for aircraft applications.

BACKGROUND OF THE INVENTION

[0003] Centrifugal pumps are commonly used to move fluid from one location to another, for example to remove fuel from an aircraft fuel tank and provide fuel to remote equipment, e.g., to a turbine engine, or to move the fuel from tank to tank. Such pumps typically have a motor and an impeller enclosed within a casing or housing. The motor rotates the impeller, which in turn draws fluid through an inlet opening in the casing and discharges the fluid (typically under pressure) through an outlet opening. One common pump has an in-line design, where the impeller includes an axially-extending stem coupled to the drive shaft of the motor. Radially extending helical blades are formed integrally with the stem of the impeller and are enclosed by an axially-extending cylindrical shroud or sleeve. The stem and helical blades rotate within the shroud to draw the fluid into a volute chamber in the housing. The volute chamber converts the kinetic energy imparted to the fluid by the impeller into pressure and discharges the fluid through the outlet in the housing. Such centrifugal pumps are available from a wide variety of manufacturers, including the assignee of the present invention. Exemplary pumps are also shown in Chiu, U.S. Pat. No. 5,427,501; Carter, U.S. Pat. No. 3,652,186; Riddall, U.S. Pat. No. 2,846,952; Kalashnikov, U.S. Pat. No. 4,275,988; Davis et al, U.S. Pat. No. 4,142,839; and Bell, U.S. Pat. No. 3,038,410.

[0004] In the Chiu pump, as in many others, the volute chamber surrounds the impeller. A discharge housing is fluidly connected and fixedly coupled to a side of the casing, and directs the flow to the appropriate location (e.g., another fuel tank, to an engine, etc.). The volute chamber and discharge housing thereby take up additional space in the tank, and require additional components. They also add weight to the pump, and overall, increase the total cost of the pump and the system.

[0005] In addition, a common requirement in aircraft applications is to maintain a fuel path if the pump is not operational, for example to maintain fuel flow to the engine in the event of a pump failure. Many pumps, particularly in-line pumps with shaft-mounted impellers, impede or prevent fuel flow through the pump when the pump is off. To create such a flow path, a by-pass fluid circuit is plumbed into the system. The by-pass fluid circuit includes tubing, valves and sometimes even additional pump(s) that are used when the pump is off. Adding a by-pass circuit in the system, of course, also adds space, requires additional components, and increases the weight and cost of the pump.

[0006] In light of the drawbacks noted above, the pumps useful for aircraft applications tend to be large in size, complex, heavy and costly. Thus, it is believed there is a demand in the aircraft industry for an in-line centrifugal pump that is compact, light in weight, and has a structure which is simple to assemble and repair, and low cost to manufacture.

SUMMARY OF THE INVENTION

[0007] The present invention provides a novel and unique in-line centrifugal pump having a motor with an integral impeller. The impeller draws fluid from an inlet to an outlet when the pump is operational, while a flow path is maintained through the pump (with negligible pressure drop) when the pump is not operational. The pump is easy to assemble, has good reliability due to few rotating parts, and has a lower weight and cost compared to the compactness of the design. The cost of the pump is thereby reduced.

[0008] According to the principles of the present invention, the pump includes a casing having an inlet and an outlet. A motor is mounted within the casing and includes an annular, rotatable rotor member and fixed stator member. A tubular shaft circumscribing a central axis is received within the rotor, and is fixed thereto. The shaft is co-axial with the inlet and outlet of the casing, and defines a central peripheral wall. An impeller includes a central, axially-extending body and a series of helical blades, where each blade extends radially outward from the central body to the inner peripheral wall. When the motor is energized, the rotor turns, which in turn causes the impeller to rotate and draw fuel through the pump from the inlet to the outlet.

[0009] When the motor stops, a flow path is maintained between the helical blades of the impeller from the inlet port to the outlet port. It has been found that there is little if any pressure drop across the impeller when the pump is non-operational which eliminates the need for a separate by-pass circuit.

[0010] The shaft includes radially-inward projecting first and second shoulders forming axial stops for the impeller. The stops axially locate the impeller within the hollow central shaft. Preferably the shaft comprises a tubular inlet end portion and a tubular outlet end portion, with each portion being concentrically aligned and having an axially overlapping section which allows the end portions to be fixed together. Each end portion carries one of the shoulders forming the shoulders for the impeller.

[0011] The central shaft further includes a pair of spaced apart, annular flange members, projecting radially outward from the shaft. Each of the inlet end and outlet end portions also carries one of the flange members. The rotor member is located between the annular flange members.

[0012] A pair of bearing members outwardly support the tubular shaft in the casing. The bearing members are located on the axial opposite side of said flange members from the rotor member, with the flange members each constituting an axial support for the bearing members.

[0013] Preferably, a vane diffuser is supported in the tubular shaft on the downstream side of the impeller to optimize the pressure conversion at the impeller exit.

[0014] Thus, as described above, an in-line centrifugal pump is provided that is easy to assemble, has good reli-
ability due to fewer rotating parts, and has a lower weight due to the compactness of the design. It is believed this reduces the costs associated with the pump.

[0015] Further features of the present invention will become apparent to those skilled in the art upon reviewing the following specification and attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. 1 is a side view of a pump constructed according to the principles of the present invention;
[0017] FIG. 2 is an end view of the pump of FIG. 1 from the inlet end;
[0018] FIG. 3 is an end view of the pump of FIG. 1 from the outlet end;
[0019] FIG. 4 is a cross-sectional side view of the pump;
[0020] FIG. 5 is an enlarged, cross-sectional side view of a portion of the pump.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0021] Referring to the drawings, and initially to FIGS. 1-4, a centrifugal pump is illustrated generally at 10, constructed according to the principles of the present invention. The centrifugal pump includes an outer pump casing or housing, indicated generally at 12, which encloses a motor, indicated generally at 14, and an impeller, indicated generally at 16. The centrifugal pump is preferably mounted in a conventional manner to a tank floor or end wall, or other appropriate support surface. Mounting pads or feet 23 extend radially outward from the bottom of housing 12 and can be attached to the support surface in a conventional manner, such as with bolts 24.

[0022] The motor casing 12 includes a body 25, having a somewhat cylindrical configuration, and being enclosed at one end by an annular inlet cover 26, and at the other end by an annular outlet cover 27. Inlet cover 26 includes an annular elongated neck portion 28 which defines an inlet port 29, while outlet cover 27 includes an annular elongated neck portion 30 which defines an outlet port 32. Neck portions 28, 30 are each concentrically aligned with each other and with the central axis “A” of the casing 12. Appropriate bolts, as at 34, fix the covers 26, 27 to the body 25, and appropriate O-ring seals as at 35 are provided between these components to ensure a fluid-tight enclosure.

[0023] The motor 14 is preferably a three-phase AC wet motor of a suitable explosion-proof sealed type for submerged operation, and includes thermal fuses for each phase. The motor 14 is located within an internal chamber 39 of the casing, and includes an annular rotor 41 surrounded by an annular stator 43. Stator 43 is sealed and fits closely within the main body 25 of the casing, and is located and fixed against rotation with respect to casing 12 by an elongated L-shaped key 45, which fits into a slot in the stator and a corresponding axial groove in the casing. An insulator layer 47 can be provided, as appropriate, between stator 43 and main body 25 as a spark arrester. Stator 43 is preferably of an otherwise conventional type, with wound coils embedded in a potting compound.

[0024] Rotor 41 is also preferably conventional in design, and closely surrounds a hollow tubular shaft, indicated generally at 50. Conventional means are used to fix the rotor with respect to the shaft, such as flanged or knurled on the inside diameter of the rotor received in indentations or serrations along the outside diameter of the shaft. The rotor could also be keyed to the shaft such as described above with the stator and housing; or generally, any other means could be used to prevent relative rotation and axial movement of the rotor along the shaft.

[0025] Shaft 50 circumscribes the central axis “A” of the pump, and defines a main fuel passage 51 through the pump shaft from inlet port 29 to outlet port 32. Shaft 50 preferably comprises a two-piece design, with an inlet end portion 52 toward inlet port 29, and an outlet end portion 54 toward outlet port 32. The outlet end portion 54 is coaxial with and axially overlaps a section of the inlet end portion 52. The outer end portion 54 can be fixed to the inlet end portion 52, such as by welding.

[0026] A pair of annular flanges 58, 59, project radially outward from shaft 50. Each flange 58, 59 has a tapered surface 60, 61, respectively (see FIG. 5), which surfaces face inwardly toward each other. The flanges 58, 59 are axially spaced apart sufficient to closely receive rotor 41, and the tapered surfaces facilitate axially locating rotor 41 along shaft 50. Preferably, one flange 58 is provided integral (preferably unitary) with outlet end portion 54; while the other flange 59 is provided integral (preferably unitary) with inlet end portion 52.

[0027] Shaft 50 is supported on a bearing structure comprising a first carbon thrust/radial bearing 63 and a second carbon thrust/radial bearing 64. First bearing 63 has one axial end located against a flat, outwardly-facing side 64a (FIG. 5) of flange 58 opposite from rotor 41, and supported on its outer diameter by the annular base 65 of a first bearing sleeve 66. A shoulder 67 projects radially inward from base 65 to support the other axial end of first bearing 63. First bearing sleeve 66 has a radially outward projecting annular arm 68 which is fixed to a sidewall 69 of body 25 via bolts as at 70.

[0028] Likewise, second bearing 64 has one axial end located against a flat, outwardly-facing side 72 (FIG. 5) of flange 59 opposite from rotor 41, and is supported on its outer diameter by the annular base 74 of a second bearing sleeve 75, and at its other axial end by radial shoulder 76. Second bearing sleeve 75 also has a radially outward projecting annular arm 77 which is fixed to a sidewall 78 of inlet cover 26 via bolts as at 80. Straight pins 82 are provided between bearings 63, 64, and their respective bearing sleeves 66, 75, to locate and prevent relative rotation thereof.

[0029] Bearings 63, 64, in conjunction with flanges 58, 59 and sleeves 66, 75 properly axially and radially locate the shaft 50, and allow smooth rotation thereof.

[0030] A slight gap or clearance is provided between the ends of shaft 50 and the adjacent portions of covers 28, 30, to prevent catching and binding; and to allow fluid communication/leakage into chamber 39 for lubrication of the bearings and to cool the motor. The use of carbon bearings, and the bearing design described above, allows the motor to dry-run, in the event of a drop in fuel, without overheating or damage to the bearings because of a loss of cooling fluid.

[0031] The impeller 16 preferably comprises an inducer type impeller which is received within and coupled to
hollow tubular shaft 50. To this end, referring now to FIG. 5, the impeller includes a central, axially-extending body 84, having a conical tapered shape, with its narrow end 85 toward the inlet port 29, and its wider end 86 toward the outlet port 32; and a series of helical or spiral blades or vanes, as at 87, which project radially outward from central body 84 to shaft 50. As should be well-known, the blades form channels which are configured to move fuel received in inlet port 29 toward outlet port 32. Blades 87 are preferably formed unitary (in one piece) with body 84, and have a common radial dimension such that they are all closely received, and preferably press-fit, within the shaft 50, and preferably within the outlet end portion 54 of the shaft 50, such that the impeller rotates with the rotation of shaft 50.

The blades 87 preferably extend the entire length of the body 84 from the narrow end 85 to the wider end 86 and can be configured in one or more flights. Preferably no additional mechanical attachment is necessary between the impeller and the shaft.

[0032] A first, radially-inward directed annular shoulder 88 is provided in outlet end portion 54 to axially locate and support one axial end 86 of impeller 16 in shaft 50; while a second, radially-inward directed annular shoulder 89 is provided by the radially smaller end of inlet end portion 52 to axially locate and support the opposite axial end 85 of impeller 16 in shaft 50.

[0033] The dimensions of the central body 84, blades 87 and shaft 50 are preferably chosen so as to maximize the capacity of the impeller for a particular application. These characteristics, as well as the rating of motor 14, can be easily determined by those of ordinary skill in the art based on such factors as the dimensions and volumetric capacity of the pump and the intended rotational speed of the impeller.

[0034] The assembly of the pump is facilitated by the above design. Specifically, the rotor 41 and stator 43 are initially located over outlet end portion 54 of shaft 50, with one end of the rotor being supported against flange 58. The impeller 16 is then inserted within the outlet end portion 54, with one end 86 of the impeller being supported against first shoulder 88. The inlet end portion 52 is then slid into the outlet end portion, with the other flange 59 supporting the other end of the rotor 41, and the second shoulder 89 supporting the opposite end 85 of impeller 16. The inlet end portion 52 and other end portion 54 are then fixed together, such as by welding. Bearing sleeves 66, 75 are attached to their respective sidewalls 69, 78, and the motor and impeller subassembly is then inserted within main body 25. Bolts 34 are then tightened down to fix covers 28, 30 to opposite ends of the main body with bearings 63, 64 located between their respective bearing sleeve and shaft portion, to enclose the motor and impeller within the housing, and allow relative rotation of the rotor and impeller therewith.

[0035] As should be appreciated, the assembly of the motor and impeller is thereby simplified, with fewer parts to reduce cost, reduce complexity, and reduce the necessity of repair and maintenance.

[0036] Referring again to FIG. 4, a vaned diffuser, indicated generally at 94, can be located in outlet cover 30, downstream from impeller 16, if necessary or desirable, to diffuse the fuel flow through the pump. Such a diffuser is illustrated as including a central, axial body 95, which narrows toward the outlet port 32, and a series of radial vanes 96. Diffuser 94 can be attached to annular neck portion 30 in an appropriate manner, such as by press-fit or welding.

[0037] Remote electrical communication with the motor of the pump is provided by an electrical connector, indicated at 98 in FIGS. 1-3. Electrical connector 98 is conventional in design, and can include for example, a multi-pronged connection for control of each phase of the motor. Other electrical connectors, or a hard-wiring connection of the pump, can also be used.

[0038] Also if necessary or desirable, a pressure transducer, indicated generally at 108, can be mounted to the housing 14 via bolts 109, to measure the pressure of fuel flow through the pump for control purposes. A passage 110 (FIG. 4) is provided internally of the casing into main fuel passage 51 for this purpose. Pressure transducer 108 is preferably of a conventional type, commercially-available in the marketplace, and chosen so as to be appropriate for the particular application. Electrical connector 98 can include additional prongs for communication with the pressure transducer, or the pressure transducer can be separately controlled.

[0039] While a specific type of motor has been described, it should be apparent to those skilled in the art that the motor could also comprise rotor and stator configurations other than as described above; as well as drive means such as an air turbine, a hydraulic motor, or any other type of means for transferring energy to mechanical motion. In any case, the dynamic requirements of the motor can be easily determined knowing the requirements of the pump, e.g., the differential head necessary, the running speed, the liquid characteristics, and the available power supply.

[0040] As should be appreciated, application of a control signal through connector 98 will energize the motor and cause rotation of rotor 41. This in turn will cause rotation of impeller 16, which will draw fuel from inlet port 29 and discharge the fuel through outlet port 32, typically under pressure. When the motor is stopped, the rotor and impeller will likewise stop rotating. As can be seen in FIG. 2, a flow path through passage 51 is maintained between the impeller blades 87 to maintain fuel flow to the downstream components of the system (e.g., to the engine). It has been found that the impeller blades do not cause significant pressure drop for the fuel flow, which thereby eliminates the need for a separate by-pass circuit.

[0041] While the present invention is particularly suited to be used as a fuel pump for aircraft applications, it is believed the pump may also be appropriate for other aerospace and non-aerospace applications where it is necessary to move a fluid from one location to another.

[0042] Thus, as described above, an in-line centrifugal pump is provided that is easy to assemble, has good reliability due to fewer rotating parts, and has a lower weight due to the compactness of the design. The pump is thereby more cost-effective to produce.

[0043] The principles, preferred embodiments and modes of operation of the present invention have been described in the foregoing specification. The invention which is intended to be protected herein should not, however, be construed as limited to the particular form described as it is to be regarded as illustrative rather than restrictive. Variations and changes
may be made by those skilled in the art without departing from the scope and spirit of the invention as set forth in the appended claims.

What is claimed is:

1. A fuel pump, comprising:

   a casing having an inlet and an outlet, a motor mounted within said casing and including a rotor member and a stator member, a tubular shaft circumscribing a central axis received within the rotor and fixed to and rotatable therewith, said tubular shaft defining an inner peripheral wall therein, an impeller axially supported and press-fit within said inner peripheral wall of the shaft, said impeller including a central, axially-extending body and a series of radially projecting blades, each blade extending radially outward from said central body to said inner peripheral wall, and electrical connection means for energizing said motor to cause rotor rotation and in turn to cause impeller rotation.

2. The fuel pump as in claim 1, and further including a vaned diffuser supported in the pump on a downstream side of the impeller.

3. The fuel pump as in claim 1, wherein the shaft includes radially-inward projecting first and second shoulders forming axial stops for each end of the impeller, the stops axially locating the impeller within the tubular shaft.

4. The fuel pump as in claim 1, wherein the tubular shaft includes a pair of spaced apart annular flange members, projecting radially outward from the shaft, and the rotor member is located between said annular flange members.

5. The fuel pump as in claim 4, and further including a pair of bearing members radially outwardly supporting said tubular shaft in said casing, said bearing members each located on an axial opposite side of said flange members from the rotor member, said flange members each constituting an axial support for the bearing members.

6. The fuel pump as in claim 5, wherein a bearing sleeve fixed to the casing supports each bearing member on i) a radially outer side; and ii) an axial end.

7. The fuel pump as in claim 6, wherein each bearing member is fixed against rotation relative to the bearing sleeve by a key member.

8. The fuel pump as in claim 1, wherein the shaft comprises an inlet end portion and an outlet end portion, each portion being concentrically aligned and having an axially overlapping section, said portions being fixed together along the overlapping section.

9. The fuel pump as in claim 8, wherein the central shaft includes a pair of spaced apart, annular flange members, projecting radially outward from the shaft, and each portion carries one of the flange members, and the rotor member is located between said annular flange members.

10. The fuel pump as in claim 8, wherein the outlet end portion includes a first radially-inward projecting shoulder forming a first axial stop for one end of the impeller, and the inlet end portion includes a second radially-inward projecting shoulder forming a second axial stop for another end of the impeller, the first and second stops axially locating the impeller within the tubular shaft.

11. The fuel pump as in claim 1, wherein the shaft comprises an inlet end portion and an outlet end portion, each portion being concentrically aligned and having an axially overlapping section, said portions being fixed together along the overlapping section, and wherein the central shaft includes a pair of spaced apart, annular flange members, projecting radially outward from the shaft, and each portion carries one of the flange members, and the rotor member is located between said annular flange members; and further including a pair of bearing members radially outwardly supporting said tubular shaft in said casing, said bearing members each located on an axial opposite side of said flange members from the rotor member, said flange members each constituting an axial support for the bearing members; and a bearing sleeve fixed to the casing supports each bearing member on i) a radially outer side; and ii) an axial end; and the outlet end portion includes a first radially-inward projecting shoulder forming a first axial stop for one end of the impeller, and the inlet end portion includes a second radially-inward projecting shoulder forming a second axial stop for another end of the impeller, the first and second stops axially locating the impeller within the tubular shaft.

* * * * *