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Modular fluid pump for use in diverse applications

Abstract

A modular fluid pump includes a stator having a plurality of stator teeth and windings that are positioned on the stator teeth. A rotor has a central shaft and substantially hemispheric ends and a plurality of magnets that define an electromagnetic communication with the windings A housing surrounds the stator and includes a fixed end cap that receives one of the hemispheric ends of the central shaft and defines a rotational axis of the rotor. A securing end cap that receives the other hemispheric end of the central shaft. The central shaft and the fixed and securing end caps define the rotational axis of the rotor. Engagement of the hemispheric end with the central shaft and the fixed and securing end caps maintains the rotor and the central shaft aligned with the rotational axis and balanced within the stator.

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Background/Summary

FIELD OF THE INVENTION

(1) The present invention generally relates to oil pumps and water pumps, and more specifically, a water or oil pump that has a modular configuration that can be used within various applications covering a broad range of possible power outputs and that can be generally customized to an ideal performance point for specific applications while maximizing common use of components and manufacturing equipment.

BACKGROUND OF THE INVENTION

(2) Water and oil pumps are used within various industries to lubricate, cool or pressurize hydraulic ports. Such pumps can be made to fit a particular application such that the various components are fundamentally custom designed for each particular design. These pumps are generally driven by an electric motor. Many automotive applications in hybrids and electric cars require high efficiency operation to minimize power draw from the battery and extend operational range of the vehicle while cooling, lubricating or pressurizing hydraulic ports. These pumps typically must fit into restricted spaces and are difficult to package with the electrical connection. Generally, the suction port and pressure ports in the applications are unique to each pump/motor combination and drive customization between the motor elements and the pump elements. This invention provides for a scalable electric pump design that includes a pumping element, a motor element, and an electrical

circuit controller element that can convert electrical energy inputs into hydraulic energy outputs for lubrication, cooling or providing hydraulic pressure. It has flexibility in the connector position and in the hydraulic output by the orientation of the motor portion and pump portion during assembly.

SUMMARY OF THE INVENTION

(3) According to one aspect of the present invention, a modular fluid pump includes a stator having a plurality of stator teeth and windings that are positioned on the stator teeth. A rotor has a central shaft and substantially hemispheric ends and a plurality of magnets that define an electromagnetic communication with the windings. A housing surrounds the stator and includes a fixed end cap that receives one of the hemispheric ends of the central shaft and defines a rotational axis of the rotor. A securing end cap that receives the other hemispheric end of the central shaft. The central shaft and the fixed and securing end caps define the rotational axis of the rotor. Engagement of the hemispheric end with the central shaft and the fixed and securing end caps maintains the rotor and the central shaft aligned with the rotational axis and balanced within the stator.

(4) According to another aspect of the present invention, a method of forming a modular fluid pump includes forming an overmolded stator having a plurality of retainer dowels extending from an end of the overmolded stator. The method also includes forming a rotor having a metallic central shaft and a plurality of magnet pockets, positioning rotor magnets in the magnet pockets, magnetically attaching a first bearing ball to a concave end of the central shaft, positioning the bearing ball and the central shaft into engagement with a concave seat of a fixed end cap defined within the housing, securing a pump body to the overmolded stator and securing a gerotor to the central shaft. The gerotor at least partially positions the central shaft and the rotor along the rotational axis. A second bearing ball is placed on another concave end of the central shaft. A securing end cap is rotationally secured onto the dowels to secure the pump body and gerotor to the overmolded stator. The securing end cap and the fixed end cap secure the first and second bearing balls and the central shaft within the rotational axis.

(5) According to another aspect of the present invention, a modular fluid pump includes a stator having a plurality of stator teeth and windings that are positioned on the stator teeth. A rotor having a central shaft with concave ends that receive bearing balls. The rotor includes a plurality of magnets that define an electromagnetic communication with the windings. A housing surrounding the stator and including a first fixed end cap that receives one of the bearing balls of the central shaft and defines a rotational axis of the rotor. A securing end cap receives the other bearing ball of the central shaft. The central shaft and the first fixed and securing end caps define the rotational axis of the rotor. Engagement of the bearing balls of the central shaft and the first fixed and securing end caps maintains the rotor and the central shaft aligned with the rotational axis and balanced within the stator. The securing end cap and the housing selectively define a plurality of locked positions that secure the securing end cap to the housing.

(6) According to another aspect of the present invention, a modular fluid pump includes a rotor having a central shaft with hemispheric ends and a plurality of magnets. A housing is overmolded onto a stator. The housing has a first end cap that includes a printed circuit board. The first end cap receives one of the hemispheric ends of the central shaft. A pump body has a gerotor that is coupled to the rotor. Operation of the rotor operates the gerotor to move a fluid from an inlet to an outlet. A plurality of retainer dowels extends through the housing and the pump body. A securing end cap includes an integral twist-lock mechanism that cooperatively engages the plurality of retainer dowels to define a locked position of the securing end cap that is free of additional fasteners. The locked position is defined by any one of a plurality of rotational positions of the securing end cap with respect to the printed circuit board and the rotational axis of the rotor. The securing end cap receives the other hemispheric end of the central shaft. The locked position of the securing end cap is further defined by a secure engagement of the housing, the pump body and the securing end cap.

(7) According to another aspect of the present invention, a modular fluid pump includes a stator having a plurality of stator teeth and windings that are positioned on the stator teeth. A rotor has a

central shaft with concave ends that receive bearing balls. The rotor includes a plurality of magnets that define an electromagnetic communication with the windings. A housing surrounds the stator and includes a first end cap that receives one of the bearing balls of the central shaft and defines a rotational axis of the rotor. A securing end cap receives the other bearing ball of the central shaft. The central shaft and the fixed and securing end caps define the rotational axis of the rotor. Engagement of the bearing balls of the central shaft and the fixed and securing end caps maintains the rotor and the central shaft aligned with the rotational axis and balanced within the stator. Operation of the rotor generates a flow of the fluid through the housing and between the rotor and the stator. The flow of the fluid engages the bearing balls to define a viscous fluid cushion at least between the bearing balls and the first end cap and the securing end cap, respectively.
(8) According to another aspect of the present invention, a modular fluid pump includes a rotor having a central shaft with hemispheric ends and a plurality of magnets. A housing is overmolded onto a stator. The housing has a first end cap that includes a printed circuit board. The first end cap receives one of the hemispheric ends of the central shaft. A pump body has a gerotor that is coupled to the rotor. Operation of the rotor operates the gerotor to move a fluid from an inlet to an outlet. A plurality of retainer dowels that extends through the housing and the pump body. A securing end cap includes the inlet and the outlet and an integral twist-lock mechanism that cooperatively engages the plurality of retainer dowels to define a locked position of the securing end cap that is free of additional fasteners, wherein the locked position defines a secure engagement of the housing, the pump body and the securing end cap. The locked position is further defined by any one of a plurality of rotational orientations of the inlet and outlet of the securing end cap with respect to the printed circuit board.
(9) According to another aspect of the present invention, a motor includes a stator having a plurality of stator teeth and a plurality of windings that are positioned on the stator teeth. A rotor has a central shaft and a plurality of magnets that define an electromagnetic communication with the windings. A housing surrounds the stator and includes a fixed end cap. A printed circuit board is attached to the fixed end cap at structural posts. Each winding of the plurality of windings defines a continuous wire that directly attaches to the printed circuit board without the use of an intermediate terminal.
(10) These and other aspects, objects, and features of the present invention will be understood and appreciated by those skilled in the art upon studying the following specification, claims, and appended drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) In the drawings:
(2) FIG. **1** is a cross-sectional view of an aspect of the fluid pump that includes the modular construction;
(3) FIGS. **2** and **2**A are side and end elevational views of a lamination stack for a stator that is used within the modular oil or water pump;
(4) FIGS. **3** and **3**A are side and end elevational views of the modular oil or water pump of FIG. **2** showing posts and wire securing features that are positioned on an end plate of the stator laminations;
(5) FIGS. **4** and **4**A are side and end elevational views of the stator of FIG. **3** showing a plan view and elevational view of the stator of FIG. **3** with the windings disposed on the teeth of the stator;
(6) FIGS. **5** and **5**A are side and end elevational views of the stator of FIG. **4** showing the plurality of retainer dowels coupled with the stator for securing a pump body and customizable end cap for the modular oil or water pump;

(7) FIGS. **6** and **6**A are side and end elevational views of the stator of FIG. **5** showing the printed circuit board positioned thereon;
(8) FIGS. **7** and **7**A are side and end elevational views of the stator of FIG. **6** showing positioning of the electrical wires of the various windings positioned on the printed circuit board;
(9) FIGS. **8** and **8**A are cross-sectional views of the stator laminations, the rotor and the retainer dowels;
(10) FIG. **9** is a schematic cross-sectional view of an aspect of the stator showing positioning of a bearing ball that is configured to be the bearing assembly for the rotor of the modular fluid pump;
(11) FIGS. **10** and **10**A are cross-sectional views of the rotor by itself and also of the rotor positioned within an aspect of the stator, respectively, and showing the configuration of the rotor positioned between the first and second bearing balls;
(12) FIG. **11** is a cross-sectional view of an aspect of the modular fluid pump of FIG. **1** and showing installation of at least one sealing assembly;
(13) FIG. **11**A is a cross-sectional view of the central shaft of FIG. **11**, taken along line XIA-XIA;
(14) FIGS. **12** and **12**A are top plan and cross-sectional views, respectively, of the modular fluid pump of FIG. **1** showing installation of the pump body that at least partially retains the rotor on the bearing ball and aligned along a rotational axis;
(15) FIG. **13** is a cross-sectional view of the modular fluid pump of FIG. **12** and showing installation of a gerotor within the pump body;
(16) FIG. **14** is a cross-sectional view of the modular fluid pump of FIG. **13** showing installation of a separate sealing assembly;
(17) FIG. **15** is a bottom plan view of a securing end cap that is positioned on the retainer dowels and rotationally secured on the pump body, and showing an aspect of a pressure bias fitting for maintaining the rotor within the rotational axis and supported at each end by a bearing ball;
(18) FIG. **15**A is a cross-sectional view of the securing end cap of FIG. **15**, taken along line XVA-XVA;
(19) FIG. **16** is a cross-sectional view of the modular fluid pump of FIG. **13** and showing rotational application of the second end cap onto the retainer dowels in a manner that is free of separate fasteners;
(20) FIG. **17** is a linear flow diagram illustrating a method for forming a modular fluid pump;
(21) FIG. **18** is a bottom perspective view of a lamination stack for a stator that is used within the modular pump;
(22) FIG. **19** is a top perspective view of the lamination stack of FIG. **18**;
(23) FIG. **20** is a top perspective view of the lamination stack of FIG. **19** with windings and terminal wires installed onto the lamination stack;
(24) FIG. **21** is an enlarged perspective view of the lamination stack and windings of FIG. **20** and showing the terminal wires located within the securing towers;
(25) FIG. **22** is a side perspective view of the lamination stack of FIG. **21** and showing installation of the retainer dowels;
(26) FIG. **23** is a side elevational view of an aspect of the retainer dowel;
(27) FIG. **24** is a bottom perspective view of the lamination stack shown with the printed circuit board attached and the terminal wires soldered to the printed circuit board;
(28) FIG. **25** is an enlarged perspective view of the printed circuit board and lamination stack of FIG. **24**;
(29) FIGS. **26**A-C are schematic views of the top and bottom sides of the printed circuit board and showing various cooling zones and attachment zones within the printed circuit board;
(30) FIG. **27** is a top perspective view of the overmolded stator for the modular pump;
(31) FIG. **28** is a top perspective view of the overmolded stator of FIG. **27**;
(32) FIG. **29** is an exploded perspective view of the overmolded stator, rotor and bearing ball for the modular pump;

(33) FIGS. **30-32** are top plan views of various aspects of the central shaft and rotor implementing various materials and configurations;
(34) FIG. **33** is a schematic view of a series of rotor configurations that are used within scalable aspects of the modular pump;
(35) FIG. **34** is a top perspective view of the rotor installed within the overmolded stator for an aspect of the modular pump;
(36) FIG. **35** is a top perspective view of an aspect of the modular pump showing connection of the pump body with the retainer dowels in the overmolded stator;
(37) FIG. **36** is a bottom perspective view of the pump body showing separating paddles that separate the pressure side from the suction side within the rotor cavity;
(38) FIG. **37** is a cross-sectional perspective view of the modular pump of FIG. **35** taken along line XXXVII-XXXVII;
(39) FIGS. **38** and **39** are top perspective views of an aspect of the modular pump showing the concave end of the central shaft and the bearing ball located on the concave end of the central shaft;
(40) FIG. **40** is a bottom plan view of the securing end cap incorporating an aspect of the bias fitting and retaining slots for attaching to the remainder of the modular pump;
(41) FIGS. **41** and **42** are perspective views of the bias fitting that is incorporated within the securing end cap;
(42) FIG. **43** is a side perspective view of an aspect of the modular oil or water pump;
(43) FIG. **44** is a first side perspective view of an aspect of the modular fluid pump;
(44) FIG. **45** is another side perspective view of an aspect of the modular fluid pump;
(45) FIG. **46** is a bottom side perspective view of an aspect of the modular fluid pump;
(46) FIG. **47** is another bottom side perspective view of an aspect of the modular fluid pump;
(47) FIG. **48** is a first side elevational view of an aspect of the modular fluid pump;
(48) FIG. **49** is a second side elevational view of the modular fluid pump of FIG. **48**;
(49) FIG. **50** is a third side elevational view of the modular fluid pump of FIG. **48**;
(50) FIG. **51** is a fourth side elevational view of the modular fluid pump of FIG. **48**;
(51) FIG. **52** is a top plan view of the modular fluid pump of FIG. **48**;
(52) FIG. **53** is a bottom plan view of the modular fluid pump of FIG. **48**;
(53) FIG. **54** is a cross-sectional view of the modular fluid pump of FIG. **52** taken along line LIV-LIV;
(54) FIG. **55** is a cross-sectional view of the modular fluid pump of FIG. **52** taken along line LV-LV;
(55) FIG. **56** is a cross-sectional view of the modular fluid pump of FIG. **52** taken along line LVI-LVI;
(56) FIG. **57** is a cross-sectional view of an aspect of the modular fluid pump and exemplifying fluid channels disposed within the rotor housing for the fluid pump;
(57) FIG. **58** is a first exploded first perspective view of the modular fluid pump of FIG. **48**; and
(58) FIG. **59** is another exploded perspective view of the modular fluid pump of FIG. **48**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

(59) For purposes of description herein, the terms “upper,” “lower,” “right,” “left,” “rear,” “front,” “vertical,” “horizontal,” and derivatives thereof shall relate to the invention as oriented in FIG. **1**. However, it is to be understood that the invention may assume various alternative orientations, except where expressly specified to the contrary. It is also to be understood that the specific devices and processes illustrated in the attached drawings, and described in the following specification are simply exemplary embodiments of the inventive concepts defined in the appended claims. Hence, specific dimensions and other physical characteristics relating to the embodiments disclosed herein are not to be considered as limiting, unless the claims expressly state otherwise.
(60) As exemplified in FIGS. **1-16** and **18-59**, reference numeral **10** generally refers to a modular fluid pump **10** that can be used within various fluid assemblies for moving materials of varying

viscosity, such as oil, water and other similar materials, from a reservoir to another location. The modular fluid pump **10** can be made to include various standard features that are included within each modular fluid pump **10**, along with various custom-made or optional features that can be added to the modular fluid pump **10** depending upon the particular application or design tolerances.

(61) Referring again to FIGS. **1-16** and **18-59**, the modular fluid pump **10**, or other similar motor for non-fluid applications, can include a stator **12** having a plurality of teeth **13** and windings **16** that are positioned on the teeth **13** of the stator **12** to form poles **14** of the stator **12**. A rotor **18** includes a central shaft **20** and a substantially hemispheric end **30** is positioned at each shaft end **22** of the central shaft **20**. A plurality of rotor magnets **84** are included that define electromagnetic communication with the windings **16**, when the windings **16** are energized by an electric current. A housing **26** surrounds the stator **12** and includes a first fixed end cap **28** that receives at least one of the hemispheric ends **30** of the central shaft **20** and defines a rotational axis **32** of the rotor **18**. A second securing end cap **34** is adapted to receive a portion of the central shaft **20** for the rotor **18** and maintain the central shaft **20** along the rotational axis **32**. The central shaft **20** and the fixed and securing end caps **28**, **34** serve to cooperatively define the rotational axis **32** of the rotor **18**. Engagement of one of the hemispheric ends **30** of the central shaft **20** with the fixed end cap **28** serves to maintain the rotor **18** and the central shaft **20** aligned with the rotational axis **32** and balanced within the poles **14** of the stator **12**. A separate securing end cap **34** can be positioned to engage the opposing hemispheric end **30** of the central shaft **20**. The securing end cap **34** engages the opposing hemispheric end **30** to secure the central shaft **20**, between the two hemispheric ends **30**, and along the rotational axis **32** of the modular fluid pump **10**.

(62) It is contemplated that the securing end cap **34** can include, in certain aspects, various custom features **36** that can be modified for a particular application. In this manner, a securing end cap **34** can be added to the modular fluid pump **10** for converting a modular fluid pump **10** to be useful in a wide range of applications and design conditions.

(63) Referring again to FIGS. **1-16** and **18-59**, the hemispheric ends **30** of the central shaft **20** are defined by separate first and second bearing balls **38** that are positioned at the concave ends **40** of the central shaft **20**. In this manner, the concave ends **40** of the central shaft **20** form a close engagement with a surface of each bearing ball **38**. This close engagement allows for a substantially smooth operation between the bearing ball **38** and each of the fixed and securing end caps **28**, **34**. Additionally, as discussed more fully below, movement of the flow **42** of fluid **44** through the modular fluid pump **10** can also direct certain amounts of the flow **42** of fluid **44** to be deposited between the engagement of the bearing ball **38** and the concave ends **40** and also between the bearing ball **38** and the concave seats **46** that are formed within the fixed end cap **28** and the securing end cap **34** for the modular fluid pump **10**. In this manner, the fluid **44** can form a viscous cushion **48** or barrier between the direct engagement of the bearing ball **38** and the other components of the modular fluid pump **10**. By using this viscous cushion **48** of the fluid **44** between the bearing ball **38** and the other components, wear between the rotor **18**, the bearing balls **38** and the other components of the modular fluid pump **10** can be diminished or substantially eliminated.

(64) In an exemplary aspect of the device, the bearing balls **38** can include a **52100** chrome moly steel bearing ball with a tight tolerance grade and a mirror surface finish. It should be understood that the bearing balls **38** can include other various sizes depending on the design of the modular fluid pump **10**.

(65) Referring again to FIGS. **1-16** and **18-59**, the concave seats **46** of the overmolded stator **12** can be integrally formed of the overmold compound **172**. The concave ends **40** of the central shaft **20** are typically round or spherically concave in form and are integrally formed from or otherwise defined within the powdered metal material of the central shaft **20**. As discussed above, the concave seats **46** and the concave ends **40** that hold the bearing ball **38** are hemispheric and are adapted to maintain a consistent film of the fluid **44** to maintain the viscous, lubricating cushion **48**

around the bearing ball **38** to reduce wear on the components.

(66) According to various aspects of the device, as exemplified in FIGS. **24-28**, the stator **12** and a printed circuit board (PCB) **142** are overmolded with the overmold compound **172** that may include a low pressure and temperature molding thermoset compound material. It is contemplated that the shape of the overmold at the PCB **142** can include a standard geometric shape that is sufficient to cover any one of a variety of configurations of the electrical components of the PCB **142**. Using a standard geometric shape, such as a cuboid, conical or cylindrical prism, a single tool can be utilized for overmolding a wide range of configurations of the PCB **142**. Within the interior of the modular fluid pump **10**, this molding process is typically used to set up the various integral function features for the modular fluid pump **10**. The formation of these features can include, but are not limited to, setting up a cooling zone **144** within the PCB **142** for cooling various electrical components **152**; protecting the electrical components **152** from damage and/or contamination; forming an integral bearing pocket **146** for receiving the bearing ball **38**; creating grooves **174** that enable active flow **42** of fluid **44** in the form of the secondary flow **194** of fluid **44** through the secondary flow path **192**; positioning on board temperature sensors **178**, or receptacles for receiving the sensors **178**, for detecting the temperature of fluid **44** moving through the secondary flow path **192**; and creating a datum plane that enables a fastenerless design. This design that is free of fasteners describes the engagement between retainer dowels **140** and the securing end cap **34**, which will be described more fully below. Additionally, the overmold of the printed circuit board **142** can define various keep out zones **148** within which various components are attached to the printed circuit board **142**.

(67) Referring again to FIGS. **1**, **11-16**, **40-42** and **54-59**, the concave seats **46** that are defined within the fixed end cap **28** and, in some embodiments, the securing end cap **34** can be in the form of hemispheric sockets that are adapted to receive a portion of the bearing ball **38** at each respective shaft end **22** of the central shaft **20** for the rotor **18**. Using this configuration, certain amounts of lash or play within the rotor **18** being positioned between the opposing hemispheric sockets may be present within the modular fluid pump **10** having the securing end cap **34**. To counteract this generally axial lash between the opposing concave seats **46**, the securing end cap **34** can include a pressure bias fitting **60** that at least partially surrounds the bearing ball **38** positioned near the securing end cap **34**. According to various aspects of the device, the pressure bias fitting **60** is placed in communication with the flow path **62** for the fluid **44** that extends between the stator **12** and the rotor **18** and through portions of the modular fluid pump **10**.

(68) Referring again to FIGS. **1**, **11-16**, **40-42** and **54-59**, during operation of the modular fluid pump **10** (rotation of the rotor **18** within the stator **12**), a flow **42** of fluid **44** is generated through the flow path **62**. This flow **42** of fluid **44** through the flow path **62** generates an axially-oriented pressure **64** within the pressure bias fitting **60**. The faster that the rotor **18** rotates, the faster the flow **42** of fluid **44** will flow through the fluid path **62**. In turn, an increase in the rate of flow **42** for the fluid **44** can result in an increase in the pressure **64** exerted within the pressure bias fitting **60** and against the bearing ball **38**. The pressure bias fitting **60** includes a pressure channel **66** that directs this pressure **64** in an axial direction and typically along the rotational axis **32** and toward the bearing ball **38**. In various aspects of the device, the bearing ball **38** can be at least partially located within the pressure channel **66** of the pressure bias fitting **60**. This axial pressure **64** compresses the bearing ball **38** near the securing end cap **34** into the central shaft **20** and along the rotational axis **32**. This axial pressure **64**, in turn, presses the central shaft **20** against the lower bearing ball **232** and into the fixed end cap **28**. Using the pressure **64** generated by the flow **42** of fluid **44** through the flow path **62**, the axial pressure **64** can axially secure the rotor **18** within the stator **12** and prevent lash, wobble, or other unwanted displacement of the rotor **18** away from or eccentric to the rotational axis **32**.

(69) As exemplified at least in FIGS. **35-59**, the pressure bias fitting **60** incorporates a bearing pocket **146** for receiving the upper bearing ball **234**. The bias fitting **60** can be made of powdered

metal to provide for superior and repeatable pocket geometry for receiving the upper bearing ball **234**. The powdered metal also provides for a porous surface finish to promote retention of fluid **44** that moves through the flow path **62**, in the form of viscous cushion **48**, for lubricating the bearing ball **38**, the bearing pocket **146** and the remainder of the bearing system, which typically includes the bearing balls **38**, the central shaft **20**, the fixed end cap **28** and the pressure bias fitting **60** of the securing end cap **34**.

(70) Referring again to FIGS. **35-59**, the pressure channel **66** for the bias fitting **60** is in the form of a small trough that extends radially from a central fitting **68** of the bias fitting **60**. Typically, the central fitting **68** is positioned at an opposite side of the bearing pocket **146**. Through this configuration, when assembled to the manifold, the central pressure fitting **60** provides a biasing pressure **64** as well as a small amount of leakage of fluid **44** to the top of the bearing pocket **146**. The pressure **64** at this interface is proportional to the pressure **64** produced by the gerotor **92** during use. As the forces within the modular fluid pump **10** are higher near the gerotor **92**, the axial loading of the central shaft **20** of the rotor **18** on the lower and upper bearing balls **232**, **234** is proportionally higher to assure that the central shaft **20** of the rotor **18** stays centered within the bearing pockets **146** that are defined within the overmolded stator **12** and the securing end cap **34**. This configuration also ensures that there is a flow **42** of fluid **44** in contact with the bearing system. When forces within the modular fluid pump **10** are low, particularly at start-up of the modular fluid pump **10**, there is little to no axial load placed along the central shaft **20**, thereby providing for ease of startup. This is particularly the case in applications of the modular fluid pump **10** that are sensorless.

(71) According to various aspects of the device, the main physical interface between the rotor **18** and the housing **26** for the modular fluid pump **10** is between the bearing balls **38** that are positioned at the concave ends **40** of the central shaft **20** for the rotor **18**. As discussed above, using the fluid **44** in the modular fluid pump **10**, these concave ends **40**, as well as the hemispheric sockets of the concave seats **46**, can form a substantially continuous fluid viscous cushion **48** surrounding the lower and upper bearing balls **232**, **234**. This viscous cushion **48** can minimize friction and wear within the engagement between the lower and upper bearing balls **232**, **234** and the central shaft **20** and hemispheric socket of the concave seat **46**. This fluid viscous cushion **48** prevents physical rubbing or direct physical contact between the central shaft **20** and the lower and upper bearing balls **232**, **234** and also between each bearing ball **38** and the respective concave seats **46**.

(72) Referring again to FIGS. **1** and **8-16** and **27-43**, in forming the modular fluid pump **10**, the components for each modular fluid pump **10** are generally similar but can vary according to size and scale. As exemplified in FIG. **33**, it is contemplated that the modular fluid pump **10** can be made according to different sizes and scales such that the modular fluid pump **10** can, as a non-limiting example, include small, medium and large versions, where each of these three versions can be made in three different heights such that nine options may be available. It is also contemplated that additional versions of the modular fluid pump **10** can also be provided that include additional heights and scales of the base components of the modular fluid pump **10**.

(73) Additionally, and as will be described more fully below, the modular fluid pump **10** can be configured to be positionable in a wide range of orientations and axes within a particular design configuration. Accordingly, the modular fluid pump **10** does not include a front or back, but can be positioned in various rotational orientations within a particular design. Additionally, the routing of various wiring can be used in conjunction with jumper connections and other configurations that can provide for a plurality of operational orientations of the modular fluid pump **10** in a range of axial configurations.

(74) Referring again to FIGS. **1**, **8-16**, **29-43** and **54-59**, the rotor **18** for the modular fluid pump **10** can include the central shaft **20** that extends through a rotor body **80** that can be overmolded out of plastic. The rotor body **80** can include a series of magnet channels or magnet pockets **82** that are

positioned parallel with the rotational axis **32** of the rotor **18** for receiving rotor magnets **84** that provide for electromagnetic communication between the rotor **18** and the windings **16** of the stator **12**. These magnet pockets **82** within the rotor body **80** can be configured to receive various types of magnets **84**.

(75) As exemplified in FIGS. **8-14** and **54-59**, the central shaft **20** can include a plurality of securing geometries **86** that interact with and serve to hold the rotor body **80** in place with respect to the central shaft **20**. These securing geometries **86** can include a variable cross-sectional thickness that varies axially along the central shaft **20**. The securing geometries **86** can also include flutes or ridges **88**, that are defined within a portion of the central shaft **20**. Because the rotor body **80** is typically molded around the central shaft **20**, the rotor body **80** directly engages and is retained within the securing geometries **86**. This engagement axially and rotationally fixes the rotor body **80** with respect to the central shaft **20**.

(76) As illustrated in the exemplary aspects of FIGS. **1-16** and **18-59**, these rotor magnets **84** that are placed in the magnet pockets **82** of the rotor **18** can include at least one of sintered neodymium, bonded neodymium, bonded ferrite and other similar magnets **84** that can be used within the rotor **18** for the modular fluid pump **10**. In addition to different types of magnets **84**, the configuration of the magnets **84** can also be varied. A single piece magnet **84** as well as a magnet **84** made of a series of laminations can be used within the rotor **18**. This variability within the use of magnets **84** and type of magnets **84** for the rotor **18** can provide for varying strengths of magnetic force generated by the rotor **18**. The differing magnets **84** can also be used to provide a customizable electromagnetic communication and customizable rotational torque that can be produced by the rotor **18** when the various windings **16** are energized.

(77) Referring again to FIGS. **11-16**, **30-37** and **58-59**, the central shaft **20** of the rotor **18** can include a double-D configuration that includes opposing planar surfaces **90** that extend along at least a portion of the central shaft **20**. The use of this “double-D” configuration, shown in cross-section in FIG. **11**A, provides a consistent and efficient locking connection between the central shaft **20** and the gerotor **92** for the modular fluid pump **10**. The double-D configuration also allows the central shaft **20** to be positioned within a molding tool in at least two configurations such that a single orientation is not necessary. The double-D configuration also provides a torque-lock of the magnet **84** in relation to the central shaft **20**. Moreover, use of the double-D configuration is important in this configuration where the central shaft **20** is supported at each concave end **40** by a bearing ball **38**. The double-D configuration is naturally symmetrical and is able to be centered along the rotational axis **32** of the rotor **18**. Therefore, counterbalancing is typically not utilized in the design of the modular fluid pump **10**.

(78) Referring again to FIGS. **1**, **8-16**, **30-37** and **54-59**, the central shaft **20** is typically made of a metallic material, such as powdered metal. In certain instances, the central shaft **20** can receive magnetic flux **100** from the magnets **84** of the rotor **18**. In such a configuration, installation of at least the lower bearing ball **232** can be performed by a magnetic connection between the lower bearing ball **232** and the central shaft **20** that may be magnetically energized through the magnetic flux **100** received from the magnets **84**. In this configuration, the lower bearing ball **232** can be magnetically coupled with the concave end **40** of the rotor **18** and the concave end **40** of the rotor **18** can be disposed within the stator **12**, with the lower bearing ball **232** magnetically coupled thereto. In this manner, the central shaft **20** of the rotor **18** can serve as the installation tool for locating the lower bearing ball **232** within the concave seat **46** located at the base of the stator **12** and within the fixed end cap **28** of the housing **26**.

(79) Referring now to FIGS. **1-8**, and **18-22**, construction of the modular fluid pump **10** can include forming the stator **12** by aligning a lamination stack **120** that forms the interior structure of the stator **12** including the teeth **13** for the stator poles **14**. In certain embodiments, the individual laminations that make up the stator **12** include stitch upsets **15** that serve as aligning features to maintain the stack of laminations **120** in an aligned configuration. Through these stitch upsets **15**,

separate fasteners are not necessary for holding the stack of laminations **120** together during formation of the stator **12**. The top lamination, rather than having a stitch upset **15**, can include an aperture that receives the vertically adjacent stitch upset **15**. This configuration ensures that the top surface of the stack of laminations **120** is level with no protruding features that may misalign the end plates **122** or other portion of the assembly.

(80) Typically, the stator **12** will be a three-phase stator **12** where three separate windings **16** are wound around the teeth **13** to form the various stator poles **14**. It should be understood that while six stator poles **14** are shown within the exemplary illustrations, other configurations of stator poles **14** can be utilized as well as different phase configurations for the motor.

(81) When the laminations **120** of stator **12** are complete, end plates **122** are placed at each end of the lamination stack **120** for securing the lamination stack **120** together. Typically, the end plates **122** are slip fit or press fit onto the opposing ends of the lamination stack **120**. Through this configuration, the stack of laminations **120** and the end plates **122** are not tightly secured together and may be separable by hand. It should be understood that rivets, bolts, welds, and other attachment mechanisms can be used to secure the lamination stack **120** together.

(82) When the lamination stack **120** is complete and the end plates **122** are in place, the windings **16** can be placed around the teeth **13** of the stator **12**. Placing the winding **16** over the teeth **13** of the stack of laminations **120** as well as the end plates **122** serves to secure the assembly together as a unitary stator **12**. The stator **12** is configured to be a three-phase winding, where three separate wires **136** are wound around the teeth **13** of the stator **12** to form the poles **14** in a predetermined configuration. After winding is complete, the terminal ends **130** of the wires **136** are secured within one of the end plates **122**. A top end plate **132** includes various securing towers **134** that can receive the terminal ends **130** of the wire **136** for the windings **16**. These securing towers **134** can receive the various terminal ends **130** of the wire **136** and hold them in a particular position during formation of the modular fluid pump **10**. These wires **136** can be in the form of various U-, V- and W-wires **136** as well as ground wires **162** that are directed from the stator **12** and the windings **16** for the stator **12**. As will be discussed more fully herein, the rotational orientation of the lamination stack **120** in relation to the fixed and securing end caps **28**, **34** is not critical and can be switched in 90-degree increments as needed for the particular design.

(83) As exemplified in FIGS. **5-6**A, and **22**, after the windings **16** are installed and the terminal ends **130** of the wires **136** are secured within the securing towers **134**, a plurality of retainer dowels **140** can be positioned through the lamination stack **120** of the stator **12** and the end plates **122**. As will be described more fully below, these retainer dowels **140** are used to hold the securing end cap **34** in place and secure the entire assembly of the modular fluid pump **10**, including the securing end cap **34** that may include custom features **36** for use in a particular design. While a rectilinear geometry for the stator **12** and the modular fluid pump **10** is illustrated, other polygonal geometries may also be implemented for generating the orientation-free design of the modular fluid pump **10**.

(84) Referring now to FIGS. **7**, **8**A and **18-26**, after the retainer dowels **140** are secured, the PCB **142** can be installed on various locating features or structural posts **150** that position the PCB **142** in a spaced arrangement apart from the terminal ends **130** and securing towers **134** of the top end plate **132**. The PCB **142** can include various electrical components **152** that can include, but are not limited to, various microprocessors, field-effect transistor (FET) drivers, drive transistors, temperature sensors **178**, wiring terminals and other similar features. As will be described more fully below, a portion of the fluid flow path **62** through the modular fluid pump **10** can pass near or in direct engagement with these electrical components **152** for providing cooling to these components during operation of the modular fluid pump **10**.

(85) Referring again to FIGS. **7**, **8**A and **18-26**, when the PCB **142** is located, the terminal ends **130** of the wires **136** for the windings **16** can be wrapped around the PCB **142** to wire terminals **154** that are located on the top surface of the PCB **142**. In this manner, a single and continuous wire **136** can form these windings **16** and the terminal end **130**. Accordingly, the terminal ends **130** can be

soldered directly to the PCB **142** at the wire terminals **154** such that no intermediary terminals are necessary between the windings **16** and the PCB **142**. This configuration of the wiring between the windings **16** and the PCB **142** can save a great deal of time, expense and resources.

(86) According to various aspects of the device, the terminal ends **130** of the wires **136** directed from the various windings **16** can be positioned on specific solder pads **156** within the PCB **142**. It is contemplated that a ground portion **160** of the PCB **142** is a solder pad **156** dedicated for attaching the various ground wires **162** that may be in contact with the stator **12**. By separating locations of solder pads **156** for the ground wires **162** from the wire terminals **154** in the form of solder pads **156**, for the terminal ends **130** of the windings **16**, additional effort in separating the wires **136** for the windings **16** from the ground wires **162** is minimized and substantially eliminated. Because these separate wires **136** are positioned on, typically, opposing sides of the PCB **142**, separate soldering operations within separated solder pads **156** can ensure that no short circuit occurs between the terminal ends **130** of the windings **16** and the ground wires **162**. The various solder pads **156** of the PCB **142** can be pre-tinned during manufacture of the PCB **142** or sometime in advance of the soldering operations that connect the wires **136** to the solder pads **156**. The pre-tinning of the solder pads can be accomplished by adding a soldering paste to the tinning pads **156**. This soldering paste can be disposed on the PCB **142** by spreading, brushing, dropping or by other similar disposition process. In various aspects of the device, the soldering paste can be printed onto the PCB **142** using a print head that disposes a specific amount of the soldering paste onto specific and pre-defined areas of the PCB **142**.

(87) Referring again to FIGS. **4-7**A and **20-26**, the placement of the wires **136** for the windings **16** and attaching these wires **136** to the solder pads **156** can be used for various aspects of the modular fluid pump **10**. Additionally, this process of placing and securing the wires **136** within the stator **12** can be utilized for a wide variety of motors. Such motors can be used for fans, impellers, pumps, drive mechanisms, stepper motors, combinations thereof and other similar types of motors. By way of example and not limitation, the use of the strain relief **292** and the grooves **292** for minimizing the strain placed on the wires **136** can be utilized within a wide range of motor applications. Similarly, utilizing a single continuous wire **136** for the winding **136** and the terminal end **130**, without using an intermediate terminal, as well as the placement of these integral terminals ends **130** on specific pre-tinned areas of the PCB **142** can also be used in a wide variety of motor related applications. Moreover, the various features of the modular fluid pump **10** described herein are applicable to a wide range of motor applications.

(88) Referring now to FIGS. **9-10**A and **22-28**, after the terminal ends **130** of the windings **16** and ground wires **162** have been soldered onto appropriate portions of the PCB **142**, the structure of the stator **12** is then overmolded with the overmold compound **172** to insulate the various components of the stator **12**. During this overmolding operation, contacts for the ground wires **162** and terminal wires **136** are allowed to protrude through the overmold for connection with electrical power and data wiring in the final installation of the modular fluid pump **10**. The overmold is performed so that the stator **12** and the controller assembly **170** typically included within (the PCB **142**) will contain various grooves **174** within the overmold compound **172** through the inner diameter **230** of the rotor **18** between the poles **14** of the stator **12**. These grooves **174** can also be located at ends of the stator teeth **13**. These grooves **174** within the overmold compound **172** of the stator **12** provide for fluid channels **176** that will provide the flow **42** between the stator **12** and rotor **18** to cool the various components and electrical components of the PCB **142**. This flow **42** of fluid **44** through the grooves **174** in the area between or near the poles **14** of the stator **12** also provides a flow **42** of fluid **44** past a thermistor or other type of temperature sensor **178** of the PCB **142** that is in thermal communication with the secondary flow path **194** that can be used to monitor the temperature of the fluid **44** moved through the modular fluid pump **10**, as well as the temperature of the various components of the modular fluid pump **10**. In addition, these grooves **174** can allow for the movement of the fluid **44** to one or both of the lower and upper bearing balls **232**, **234** for

providing the viscous fluid cushion **48** described above.

(89) As exemplified in FIGS. **1**, **13-16**, **27-29** and **43-59**, during operation of the rotor **18** within the stator **12**, a primary flow **196** of fluid **44** is moved through the modular fluid pump **10** that provides the primary movement of the viscous fluid **44** through the modular fluid pump **10**. The grooves **174** that are formed by the overmold compound **172**, typically in the form of a type of resin or other polymer material, provide for a secondary flow path **192** that diverts a portion of the fluid flow **42** toward the PCB **142**, the temperature sensor **178** and one or both of the bearing balls **38** of the modular fluid pump **10**. It is contemplated that the secondary flow **194** of fluid **44** through the secondary flow path **192** is substantially smaller than the primary flow **196** of fluid **44** so that operation of the modular fluid pump **10** is not overly diminished by moving the secondary flow **194** of fluid **44** through the secondary flow path **192**. The use of the secondary flow path **192** provides for more efficient and consistent operation of the modular fluid pump **10**. Additionally, the secondary flow path **192** is small enough that is does not adversely diminish the performance of the modular fluid pump **10**.

(90) The flow **42** of the fluid **44** through the primary and secondary flow paths **198**, **192** is performed by operation of the gerotor **92**. The gerotor **92** is directly connected with the central shaft **20** so that when the modular fluid pump **10** is activated, an electrical current is moved through at least a portion of the windings **16** in the stator **12**. This activation of the winding, generates an electromagnetic force (EMF) that rotates the rotor **18** with respect to the poles **14** of the stator **12**. Because the gerotor **92** is connected with the rotor **18**, the operation of the rotor **18**, in turn, operates the gerotor **92**. The various flow pockets **210** generated through operation of the gerotor **92** provides for the movement of fluid **44** through the inlet **212**, through the primary flow path **198** as well as the secondary flow path **192**, and in through an outlet **214** of the modular fluid pump **10**.

(91) Referring now to FIGS. **11-15**A and **29-39**, after the stator **12** is overmolded, the rotor **18** can be positioned within the inner diameter **230** of the stator **12**. As discussed above, the lower bearing ball **232** can be positioned within the concave seat **46** of the fixed end cap **28** by placing the first or lower bearing ball **232** on the shaft end **22** of the central shaft **20**, as well as the second or upper bearing ball **234**. Magnetic flux **100** from the magnets **84** of the rotor **18** can energize the central shaft **20** to form a magnetic field that can be used as a magnet **84** for holding the lower bearing ball **232**. By magnetically attaching one or both of the bearing balls **38** to the concave ends **40** of the central shaft **20**, the central shaft **20** can be used as the tool for locating the lower bearing ball **232** within the concave seat **46** defined within the fixed end cap **28** of the modular fluid pump **10**.

(92) Typically, the rotor **18** for the modular fluid pump **10** will include four magnets **84** that cooperate electromagnetically with the six poles **14** of the stator **12**. Where a different configuration of poles **14** for the stator **12** are included, it is typical that the configuration of the magnets **84** for the rotor **18** will also change. Typically, the number of magnets **84** for the rotor **18** is different than the number of poles **14** for the stator **12**, such that when the windings **16** of the stator **12** are energized, the produced EMF will generate a rotation of the rotor **18** within the stator **12**.

(93) It is contemplated that various sealing assemblies **110** can be included within the overmolded stator **12** and the pump body **240** that holds the gerotor **92**. The various sealing assemblies **110** can retain O-rings **112** therein. The pump body **240** can be attached to the overmolded stator **12** and placed over the retainer dowels **140**. Within the pump body **240**, the gerotor **92** at least partially positions and aligns the position of the central shaft **20** to set the rotational position to rotate the magnets **84** about the central shaft **20**. As discussed above, the pump body **240** and the gerotor **92** can be positioned in various rotational positions with respect to the overmolded stator **12**. It is contemplated that the positioning of the pump body **240** can determine which of the plurality of grooves **174** or fluid channels **176** defined between (or along) the poles **14** of the stator **12** will serve as the secondary flow path **192** for the secondary flow **194** of fluid **44**.

(94) By way of example, and not limitation, the pump body **240** can include an in-port **250** and an out-port **252** that define a secondary flow path **192**. The in-port **250** can align with a corresponding set of grooves **174** in each rotational position with respect to the rectangular body of the modular fluid pump **10**. Accordingly, regardless of the positioning of the pump body **240** and the gerotor **92**, the pump body **240** and gerotor **92** will typically be in alignment with a corresponding set of grooves **174** that are defined proximate the poles **14** of the stator **12**. The orientation of the pump body **240** and the gerotor **92** can be changed depending upon the exact configuration of the device incorporating the modular fluid pump **10**.
(95) In various aspects, it is also contemplated that the exact orientation of the pump body **240** may not be an essential consideration such that the orientation of the pump body **240** is less critical in forming the modular fluid pump **10**, so long as the gerotor **92** is aligned with the rotational axis **32** of the rotor **18**. As will be described more fully below, the pump body **240** and the securing end cap **34** are configured to be aligned with the stator **12** and the PCB **142** in a plurality of rotational positions. These rotational positions are typically 90-degree increments that correspond to the placement of the retainer dowels **140**. Other degree increments can be utilized where the geometry of the modular fluid pump **10** has other polygonal shapes.
(96) As exemplified in FIGS. **34-42** and **54-59**, the gerotor **92** and pump body **240** form a cavity for the gerotor **92** that at least partially defines the primary flow path **198**. The pump body **240** also includes flow ports that extend through the pump body **240** to channel a pressured flow **42** of fluid **44** from a pressure side of the gerotor **92** and down the grooves **174** that form the secondary flow path **192**, and wherein the flow ports also allow for a return of pressured flow **42** of fluid **44** through the secondary flow path **192** and to a suction side of the gerotor **92**. Additionally, the pump body **240** includes a wall of material that divides the pressure side of the gerotor **92** from the suction side of the gerotor **92**, wherein the wall of material serves to bias a flow **42** of the fluid **44** into the grooves **174** that form the secondary flow path **192** to define the secondary flow **194** of fluid **44**. This wall of material can include one or more, and typically two, paddles **242** that are typically stationary and are positioned near the central shaft **20** of the rotor **18**. These paddles **242**, which extend downward from the pump body **240**, separate the pressure side from the suction side in the rotor cavity **244**. This serves to direct the secondary flow **194** of fluid **44** down the molded grooves **174** that define the secondary flow path **192**. This secondary flow **194** of fluid **44** serves to lubricate the bearing ball **38** and also cool various components of the PCB **142**. In addition to the secondary flow **194** of the fluid **44**, it is contemplated that an internal grease can also be utilized for providing lubrication to the internal components of the modular fluid pump **10**.
(97) Referring again to FIGS. **14-16**, **35-39** and **54-59**, after the pump body **240** and the gerotor **92** are placed on the overmolded stator **12**, the base form **260** of the modular fluid pump **10** is substantially complete. This assembly may not be secured onto the retainer dowels **140**. According to various aspects of the device, the securing end cap **34** of the modular fluid pump **10** can be rotationally secured onto the retainer dowels **140** to secure the components together to form the modular fluid pump **10**. The retainer dowels **140** can include multiple lengths that correspond to varying lengths of the stator **12**. The varying lengths of the retainer dowels **140** also accommodate varying dimensions of the pump body **240** and the securing end cap **34**.
(98) Referring to FIGS. **14-16** and **40-59**, the securing end cap **34** of the modular fluid pump **10** can include a standard side **270** that engages the pump body **240** and the gerotor **92**. This standard side **270** may be of a configuration that is substantially similar among the various designs of the modular fluid pump **10**. Opposite the standard side **270** is the custom side **272** where various components of a particular design will be implemented within the securing end cap **34**. On the standard side **270**, one or more retaining slots **274** can be defined within the material of the securing end cap **34**. These retaining slots **274** can include an eye-slot that can receive a slotted end **276** of each retainer dowel **140**. When the slotted end **276** of each retainer dowel **140** enters the eye of the retaining slot **274**, rotation of the securing end cap **34** moves the slotted end **276** of each

dowel through the retaining slot **274** and secures each slotted end **276** of the retainer dowel **140** within a corresponding retaining slot **274**.

(99) It is also contemplated that the retaining slots **274** included within the securing end cap **34** can be sloped such that rotation of the securing end cap **34** also biases the securing end cap **34** against each retainer dowel **140** and biases the securing end cap **34** against the pump body **240** compress the O-rings **112** within the sealing assemblies **110** and to form a substantially fluid-tight fit that defines any one of a plurality of locked positions **278** of the securing end cap **34**. Various detents can be included within the retaining slots **274** of the securing end cap **34** to substantially secure the slotted end **276** of each retainer dowel **140** within the cooperating slots of the securing end cap **34**. In this manner, formation of the modular fluid pump **10** can be accomplished without the need of fasteners such as bolts, screws, welds, and other attaching mechanisms and methods that may be used in conventional fluid pumps for securing components together.

(100) Because the modular fluid pump **10** is secured together through the twist-lock rotational engagement of the securing end cap **34** with the retainer dowels **140**, the number of holes that need to be drilled within the modular fluid pump **10** are substantially diminished and opportunities for leaks within the modular fluid pump **10** are also diminished. Through this configuration, the anchoring of the modular fluid pump **10** can be accomplished primarily through three components in the stack of the modular fluid pump **10**, in the form of the overmolded stator **12**, the pump body **240** (which combine to form the base form **260**) and the manifold that is typically in the form of a securing end cap **34** of the modular fluid pump **10**. Through the configuration of the biasing or retaining slots **274** in the securing end cap **34**, the twist-lock mechanism or configuration of the securing end cap **34** provides a biasing fit between the securing end cap **34** and the pump body **240** to hold the various components of the modular fluid pump **10** together. Because the pump body **240** and the securing end cap **34** include machined features, these components can hold and account for the required tolerances within the modular fluid pump **10**.

(101) Referring again to FIGS. **4-8**A and **20-26**, and as discussed above, the wires **136** that extend from the windings **16** into PCB **142** include no intermediate terminals. The securing towers **134** included within the top end plate **132** provide a strain relief **290** on the winding wire **136** and also provide a structural channel to direct the wire **136** from the windings **16** to the strain relief **290** on the edge of the PCB **142**. This strain relief **290** can include strain relief notches **292** that are positioned at an outer edge of the PCB **142**. Structural support is also provided to the PCB **142** for folding and holding the wire **136** to the PCB **142** while soldering to pre-tinned solder pads **156**. This structure for the PCB **142** is provided by the heat stake posts **150** that extend upward from the top end plate **132** positioned at one of the ends of the lamination stack **120** that form the stator **12**. These posts **150** are incorporated within the top end plate **132** for providing support to the PCB **142**. When various operations are performed on the PCB **142**, such as soldering, folding wires **136**, and other similar operations, the heat stake posts **150** provide structure underneath the PCB **142** to support and prevent damage to the PCB **142** during manufacture. Additionally, the space between the top end plate **132** and the PCB **142** that is defined by the heat stake posts **150** can also provide for at least a portion of the secondary flow path **192** through which the secondary flow **194** of fluid **44** can move to provide cooling to the components of the PCB **142**.

(102) According to various aspects of the device, as exemplified in FIGS. **11-14**, it is contemplated that at least one flux collector pocket **310** can be disposed within the stator **12** after the windings **16** are positioned on the poles **14** of the stator **12**, but before the overmold compound **172** covers the stator **12**. These flux collector pockets **310** can serve to channel a magnetic field from the rotor **18** and direct this magnetic field to a Hall Effect sensor on the PCB **142**. The Hall Effect sensor can be used for optional sensor communication for assessing the rotational position of the rotor **18** with respect to the stator **12**. In certain conditions, the flux collector pockets **310** can be installed in each design of the modular fluid pump **10**. It should be understood that the flux collector may not be required in each implementation of the modular fluid pump **10**. In configurations where sensorless

commutation of the rotor **18** is desired, no flux collector pocket **310** may be included within the stator **12**.

(103) Referring again to FIGS. **1-16** and **18-59**, the various configurations of the modular fluid pump **10** can include various standard components that most, if not all, implementations of the modular fluid pump **10** will typically include. Such components can include, but may not be limited to, the rotor **18**, central shaft **20** and rotor body **80** with the magnet pockets **82**. As discussed above, the exact configuration and material of the magnets **84** for the rotor **18** may be changed depending upon the exact use and implementation of the modular fluid pump **10**. The stator **12**, poles **14**, and windings **16** will typically be included as standard parts of each design of the modular fluid pump **10**. Additionally, the wires **136** for the windings **16** and ground wires **162** will also typically be included within each design of the modular fluid pump **10** as well as the connections with the PCB **142**. The overmold compound **172** surrounding the stator **12**, the retainer dowels **140** and the PCB **142** will also typically be standard components within each aspect of the modular fluid pump **10**. Within the modular fluid pump **10**, various custom features **36** can also be included. These custom features **36** can also include, as discussed above, the material for the magnets **84** disposed within the magnet pockets **82** of the rotor **18**, the rotational position of the gerotor **92** and pump body **240** with respect to the stator **12**, the use of jumper connectors with the PCB **142** for orienting the position of the modular fluid pump **10** within a particular application, the exact configuration of the securing end cap **34** or manifold. As discussed above, the securing end cap **34** can include the custom side **272** having various design specific features that are useful for attaching or otherwise incorporating the modular fluid pump **10** within a particular application, setting or design.

(104) As exemplified in FIGS. **35-59**, the gerotor **92** is installed within the pump body **240**. In various aspects of the device, the gerotor **92** for the modular fluid pump **10** can include a plurality of displacement configurations that can vary by thickness and/or diameter, according to corresponding changes to the configuration of the pump body **240**. Accordingly, the modular fluid pump **10** can be designed having various pump bodies **240** that come in different widths that match corresponding widths of the stator **12** as an extrusion blank. Typically, three different configurations of pump body **240** will be provided to match the corresponding widths of the stator **12**. The variable configuration of the pump body **240** and the stator **12** enables flexibility in either the thickness of the pump body **240** or the gerotor pocket diameter with a simple change to the machine program to accommodate three configurations of gerotors **92**. After the gerotor **92** is installed within the pump body **240**, the upper bearing ball **234** is positioned at the concave seat **46** at the end of the central shaft **20** of the rotor **18**.

(105) Through the use of the modular fluid pump **10**, it is contemplated that a single modular fluid pump **10** or family of modular fluid pumps **10** can be manufactured. These modular fluid pumps **10** can be, after manufacture, customized for incorporation within a particular specific application or design. The customizable features included within the modular fluid pump **10** allow for changes in orientation, certain materials, axial configuration and other aspects that allow the modular fluid pump **10** to be incorporated within a wide range of applications or designs.

(106) Referring now to FIGS. **1-59**, having described various aspects of the modular fluid pump **10**, a method **400** is disclosed for manufacturing a modular fluid pump **10**. According to the method **400**, an overmolded stator **12** is formed having a plurality of retainer dowels **140** that extend from an end of an overmolded stator **12** (step **402**). A rotor **18** is also formed, where the rotor **18** includes a metallic central shaft **20** and a plurality of magnet pockets **82** or recesses (step **404**). The magnets **84** can then be disposed within each magnet pocket **82** defined within the rotor **18** (step **406**). A bearing ball **38** can be magnetically attached to a concave end **40** of the central shaft **20** (step **408**). As discussed above, positioning of the magnets **84** within the rotor **18** can generate a magnetic flux **100** that provides the central shaft **20** with magnetic properties that may be sufficient to hold the bearing ball **38** in place during installation of the rotor **18**. According to the

method **400**, the bearing ball **38**, typically the lower bearing ball **232**, and the central shaft **20** are then positioned into engagement with a concave seat **46** of the fixed end cap **28** (step **410**). As discussed above, because the central shaft **20** is magnetically energized through the magnetic flux **100** provided by the rotor magnets **84**, the central shaft **20** can act as a tool for retaining and positioning the lower bearing ball **232** within the concave seat **46** of the fixed end cap **28**. The pump housing **26** can then be secured to the overmolded stator **12** and the retainer dowels **140** (step **412**). A gerotor **92** is then secured to the central shaft **20** within the pump body **240** (step **414**). The gerotor **92** at least partially positions the central shaft **20** and the rotor **18** along rotational axis **32**. The securing end cap **34** is then rotationally secured onto the slotted ends **276** of the retainer dowels **140** (step **416**). In this manner, the securing end cap **34** provides a twist-lock configuration that secures the securing end cap **34** to the retainer dowels **140** without the use of additional fasteners. This fastener-less configuration of the modular fluid pump **10** prevents the unnecessary use of fastener holes and other apertures that may be included within conventional fluid pumps.
(107) As exemplified in FIGS. **1-59**, the manifold in the form of the securing end cap **34** is seated within the retainer dowels **140** and is rotated into place to provide a compression load onto the remainder of the modular fluid pump **10**, in particular, the various O-rings **112**. As discussed herein, the overmolded stator **12** can be assembled in, typically, 90 degree increments to locate the electrical/data connector **320** on any side of the pump **40** without affecting motor or hydraulic functions of the modular fluid pump **10**. Through this modular configuration of the modular fluid pump **10**, the various configurations of the pump **10** can provide a wide range of advantages. These advantages can include, but are not limited to, pressure ranges of up to approximately 10 bar, flow ranges of up to approximately 14 liters per minute, temperature ranges from approximately −40 degrees Celsius to approximately 150 degrees Celsius (exposure), functional ranges from approximately −40 degrees Celsius to approximately 125 degrees Celsius (duty and fluid dependent), voltage variants from 12 VDC, 24 VDC and 48 VDC, sealed to IP6K9K for internal or external applications, included provisions for electromagnetic compatibility, censored or sensorless configurations, communication capable for CAN, LIN, PWN, on/off and other communications formats, onboard temperature sensing, full diagnostic logging and recording, fault storage black box, low noise construction, flexible architectures to suit demanding packaging constraints, and customer specific manifold for flexible mounting configurations.
(108) The various components contained within the modular fluid pump **10**, and the processes used for manufacturing and operating the modular fluid pump **10**, as described herein can be utilized with in any one of various fluid pump designs. In addition, these components and processes described herein are also able to be implemented within other types of motors in both fluid-related and non-fluid related designs and applications.
(109) It is to be understood that variations and modifications can be made on the aforementioned structure without departing from the concepts of the present invention, and further it is to be understood that such concepts are intended to be covered by the following claims unless these claims by their language expressly state otherwise.

Claims

1. A modular fluid pump comprising: a stator having a plurality of stator teeth and windings that are positioned on the plurality of stator teeth; a rotor having a central shaft and substantially hemispheric ends and a plurality of magnets that define an electromagnetic communication with the windings; a housing surrounding the stator and including a fixed end cap that receives one of the hemispheric ends of the central shaft and defines a rotational axis of the rotor; and a securing end cap that receives the other hemispheric end of the central shaft, wherein the central shaft and the fixed and securing end caps define the rotational axis of the rotor, wherein engagement of the hemispheric ends with the central shaft and the fixed and securing end caps maintains the rotor and

the central shaft aligned with the rotational axis and balanced within the stator, wherein the securing end cap includes a pressure bias fitting that directs an axial pressure generated during operation of the rotor through a pressure channel and onto one of the hemispheric ends and along the rotational axis, wherein the axial pressure limits lash within the central shaft of the rotor along and eccentric to the rotational axis.

2. The modular fluid pump of claim 1, wherein the hemispheric ends are defined by bearing balls that are positioned within concave ends defined within each hemispheric end of the central shaft.

3. The modular fluid pump of claim 2, further comprising: a pump body that is coupled between the stator and the securing end cap; and a gerotor positioned within the pump body, wherein operation of the rotor rotates the gerotor, and wherein operation of the gerotor is configured to move a fluid through a flow path defined within the securing end cap and the pump body.

4. The modular fluid pump of claim 1, wherein the rotor includes magnet pockets that are adapted to receive a rotor magnet of the plurality of magnets within each respective magnet pocket.

5. The modular fluid pump of claim 1, wherein the plurality of magnets can include one of sintered neodymium, bonded neodymium and bonded ferrite.

6. The modular fluid pump of claim 1, wherein the fixed end cap is attached to the stator and includes structural posts that support a position of a printed circuit board relative to the housing.

7. The modular fluid pump of claim 3, wherein the stator and the housing include a plurality of retainer dowels that extend from one side of the housing proximate the securing end cap, wherein the securing end cap couples to the plurality of retainer dowels in a twist-lock rotational engagement that is free of additional fasteners.

8. The modular fluid pump of **7**, wherein the securing end cap includes a plurality of retaining slots that receive and rotationally secure the plurality of retainer dowels to compress the securing end cap, the pump body, the rotor, the bearing balls and the housing together in a secure assembly.

9. The modular fluid pump of claim 3, wherein the housing is defined by an overmold compound that completely surrounds the stator, and wherein the housing is substantially orientation free with respect to a position of the housing in relation to the securing end cap.

10. The modular fluid pump of claim 1, wherein the securing end cap and the housing can be secured in a plurality of rotational positions relative to the rotational axis of the central shaft.

11. The modular fluid pump of claim 10, wherein the plurality of rotational positions are configured to be in 90 degree increments about the rotational axis of the central shaft.

12. The modular fluid pump of claim 9, wherein the overmold compound of the housing includes a plurality of grooves that defines a secondary flow path through a portion of a rotor cavity, wherein during operation of the rotor, the gerotor is configured to move a primary flow of the fluid through a primary flow path and also move a secondary flow of the fluid through the secondary flow path.

13. The modular fluid pump of claim 12, wherein the secondary flow path directs the secondary flow of the fluid proximate a printed circuit board and in thermal communication with the printed circuit board to cool electrical components of the printed circuit board.

14. A modular fluid pump comprising: a stator having a plurality of stator teeth and windings that are positioned on the plurality of stator teeth; a rotor having a central shaft and substantially hemispheric ends and a plurality of magnets that define an electromagnetic communication with the windings; a housing surrounding the stator and including a fixed end cap that receives one of the hemispheric ends of the central shaft and defines a rotational axis of the rotor; and a securing end cap that receives the other hemispheric end of the central shaft, wherein the central shaft and the fixed and securing end caps define the rotational axis of the rotor, wherein engagement of the hemispheric ends with the central shaft and the fixed and securing end caps maintains the rotor and the central shaft aligned with the rotational axis and balanced within the stator, wherein the fixed end cap is attached to the stator and includes structural posts that support a position of a printed circuit board relative to the housing.

15. The modular fluid pump of claim 14, wherein the stator and the housing include a plurality of

retainer dowels that extend from one side of the housing proximate the securing end cap, wherein the securing end cap couples to the plurality of retainer dowels in a twist-lock rotational engagement that is free of additional fasteners.

16. The modular fluid pump of **15**, wherein the securing end cap includes a plurality of retaining slots that receive and rotationally secure the plurality of retainer dowels to compress the securing end cap, a pump body that is positioned between the stator and the securing end cap, the rotor, and the housing together in a secure assembly.

17. The modular fluid pump of claim 14, wherein the securing end cap and the housing can be secured in a plurality of rotational positions relative to the rotational axis of the central shaft.

18. The modular fluid pump of claim 17, wherein the plurality of rotational positions are configured to be in 90 degree increments about the rotational axis of the central shaft.

19. A modular fluid pump comprising: a stator having a plurality of stator teeth and windings that are positioned on the plurality of stator teeth; a rotor having a central shaft and substantially hemispheric ends and a plurality of magnets that define an electromagnetic communication with the windings; a housing surrounding the stator and including a fixed end cap that receives one of the hemispheric ends of the central shaft and defines a rotational axis of the rotor; and a securing end cap that receives the other hemispheric end of the central shaft, wherein the central shaft and the fixed and securing end caps define the rotational axis of the rotor, wherein engagement of the hemispheric ends with the central shaft and the fixed and securing end caps maintains the rotor and the central shaft aligned with the rotational axis and balanced within the stator, wherein the hemispheric ends are defined by bearing balls that are positioned within concave ends defined within each hemispheric end of the central shaft, and wherein the stator and the housing include a plurality of retainer dowels that extend from one side of the housing proximate the securing end cap, wherein the securing end cap couples to the plurality of retainer dowels in a twist-lock rotational engagement that is free of additional fasteners.

20. The modular fluid pump of **19**, wherein the securing end cap includes a plurality of retaining slots that receive and rotationally secure the plurality of retainer dowels to compress the securing end cap, a pump body that is positioned between the stator and the securing end cap, the rotor, and the housing together in a secure assembly.