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(54) **Concentric multi-stage centrifugal pump with start stage**

(57) A multi-stage centrifugal pump includes a start stage. An inner impeller stage is driven by drive shaft while an electric motor drive is selectively switched on for starting, and off for normal operation to

drive an outer impeller stage. The electric motor driven outer stage builds required system pressure and flow at engine starting, and then permits the electric motor to be switched off and allow the outer stage to act as a free rotating disk to improve operating efficiency of the pump.

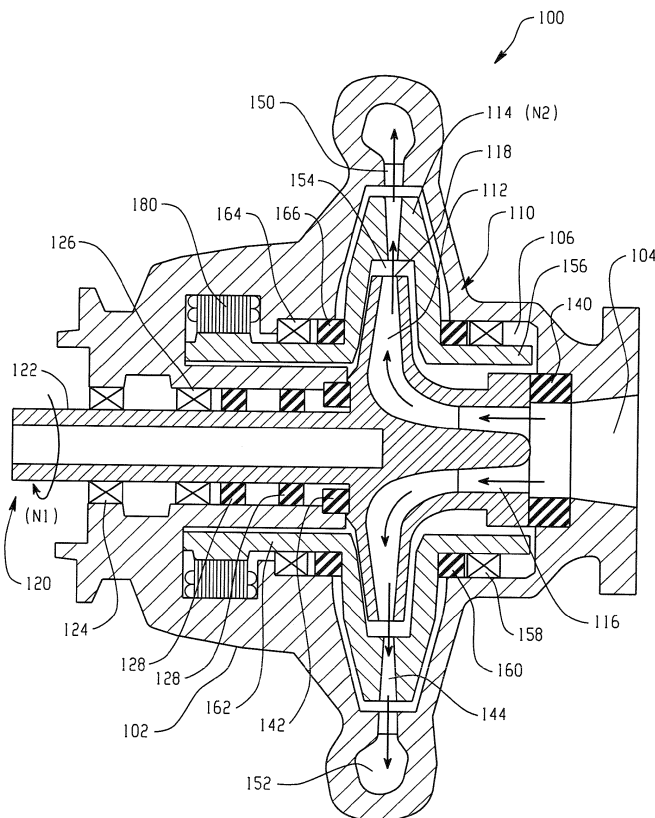


Fig. 1

Description

Background of the Disclosure

[0001] This disclosure relates to a pump, and more particularly to a high speed centrifugal pump, with the addition of a start stage. However, selective details may find application in related pump environments.

[0002] Centrifugal pumps are generally well known in the art. Generally speaking, an axial inlet provides fluid to a rotating impeller. A first stage impeller is driven by a rotating drive shaft so that the first stage impeller imparts energy to the fluid which exits generally radially from the first stage. Typically, axially spaced bearings are disposed along an outer surface of the shaft to support the shaft and impeller within the pump housing. The impeller is located within a pumping cavity of the housing and seals are provided on front and rear faces of the impeller so that the pressure build-up from the rotating impeller is imparted to the fluid within the pump cavity. A stationary diffuser is provided at a radial outer location of the impeller and receives the fluid from the impeller. The diffuser converts high velocity fluid energy into lower velocity fluid energy thereby increasing the pressure of the fluid as the fluid is directed to a discharge passage.

[0003] Such centrifugal pumps are used in a wide variety of applications. One such application is providing high pressure fuel flow to a jet engine, for example. This environment requires a minimal pump packaging volume, and also a minimal weight. Optimizing pump performance and particularly optimizing pump performance at engine start-up in order to build the desired or required system pressure and flow is desired. However, once the start-up pressure and flow is established, it is important to limit the impact of the starting components on operation of the pump.

[0004] Therefore, a need exists for a compact package of a high-speed centrifugal pump that also has reduced weight and satisfies start stage requirements for the system.

Summary of the Disclosure

[0005] A centrifugal pump assembly includes a first pump stage, a second pump stage independently rotatable relative to the first pump stage, and a drive assembly that rotates the first and second pump stages to a first speed and then rotates the second pump stage at a different speed than the first pump stage.

[0006] In one embodiment, the second pump stage becomes freely rotating at a selectable operating condition.

[0007] The second impeller stage may rotate faster at start-up and then rotate at approximately one-half of the speed of the first pump stage speed.

[0008] In one arrangement, the second pump stage rotates at a slower speed based on a fluidic drive provided by the driven first stage speed.

[0009] A first pump stage is an inner impeller stage,

and the second pump stage is preferably a concentric, outer impeller stage.

[0010] The drive assembly includes a main drive shaft connected to and selectively rotating the first pump stage.

[0011] The drive assembly includes a separate drive member for rotating the second pump stage independently of the first pump stage.

[0012] In one arrangement, the separate drive member is an electric motor drive.

[0013] The electric motor drive may be concentrically located about the main drive shaft and adapted to rotate the second pump stage at a different speed than the main drive shaft rotates the first pump stage.

[0014] Consequently, at start-up, the outer stage may rotate at a high speed to increase the pressure.

[0015] After start-up, the second, outer stage rotates slower since the outer impeller stage is only fluidically coupled to the inner impeller stage.

[0016] A method of operating the centrifugal pump assembly includes providing first and second pump stages. The method includes independently driving the first and second pump stages.

[0017] Once start-up speed is attained, a positive drive for the second pump stage may be turned off and the second pump stage allowed to freely rotate.

[0018] In another arrangement, the concentric outer stage can be driven with not only the fluidic drive but also the second, outer stage drive motor and continue to drive the second pump stage if so desired.

[0019] The driving step includes using an electric drive motor for rotating the second pump stage so that the first and second pump stages may be driven at different speeds.

[0020] A primary benefit is a reduction in disk drag associated with the high speed centrifugal pump using multiple stages.

[0021] Another benefit is associated with the minimal pump packaging volume, for example by placing the first and second pump stages disposed in concentric fashion.

[0022] Still another advantage resides in the reduced weight while providing for start-up.

[0023] Still other benefits and advantages of the present disclosure will become apparent upon reading and understanding the following detailed description.

Brief Description of the Drawing

[0024] Figure 1 is a cross-sectional view of a preferred embodiment of the present disclosure.

Detailed Description

[0025] As shown in Figure 1, a pump assembly, and more particularly a centrifugal pump assembly 100, includes a housing 102 having an inlet 104 shown here as an axial inlet that communicates with a pump cavity or chamber 106. Received in the pump chamber is a rotary pump 110 and specifically a multi-stage rotary pump pro-

vided by a first or inner impeller stage 112 and a second or outer impeller stage 114. The first stage is in fluid communication with the inlet so that an axial passage 116 receives the fluid from the inlet 104 and through rotation of the inner impeller stage, provides fluid at a higher pressure to radial outlet 118.

[0026] The inner impeller stage 112 is positively driven by a portion of the drive assembly 120, and more particularly by drive shaft 122 that rotates the inner impeller stage at a desired speed. Preferably the drive shaft 122 is supported and axially spaced locations by first and second bearings 124, 126 that support the drive shaft for relative rotation with respect to the housing 102. In addition, seals 128 are typically provided and extend between the outer surface of the drive shaft and an inner wall of the passage in the housing that receives the drive shaft 122. In addition, a first impeller seal 140 is provided adjacent the inlet 104 and seals between the inner, front surface of the inner impeller stage 112 and the inlet 104 while a second or rear seal 142 is disposed along a rear surface or rear face of the inner impeller stage 112 and the housing 102. Thus, as the first impeller stage 112 is rotated by the drive shaft 122, fluid from the inlet 104 proceeds through passages 116 to the outlets 118.

[0027] Also received within the pump chamber 106 is the second or outer impeller stage 114. Preferably, the outer impeller stage 114 is concentrically located relative to the inner impeller stage 112. That is, a radially extending passage 144 receives fluid from the outlet 118 of the inner impeller stage, and imparts additional energy from the outer impeller stage 114 before the fluid exits and communicates with a stationary diffuser 150 that leads to discharge passage 152. The outer impeller stage 114 includes a recess 154 dimensioned to closely receive the outer radial dimension of the inner impeller stage 112. An axially extending portion of the outer impeller stage has a first portion 156 that is received in the pump chamber in radially spaced location relative to the inlet end of the inner impeller stage. The first axial portion 156 is supported by an outer stage bearing 158 that supports the outer impeller stage for relative rotation with respect to the housing 102. In addition, seal 160 is interposed between the first axial portion 156 and an inner surface that defines the pump chamber in the housing. Similarly, a second axial portion 162 extends rearwardly and is supported by a second outer stage bearing 164 and receives a seal 166 between the second axial portion and the pump housing 102.

[0028] A second portion of the drive assembly 120 is provided by an outer stage drive motor 180 which in this particular instance is an electric drive motor. This drive motor 180 provides for positive independent driving movement of the outer impeller stage 114 relative to the inner impeller stage 112. There are situations where it is desirable to use the drive motor 180 to positively drive the outer impeller stage 114 at a different speed than the inner impeller stage. Of course, one skilled in the art will also appreciate that the inner and outer impeller stages

112, 114 could be driven at the same speed if so desired. By using an independent outer stage drive motor 180, the outer stage can be positively driven or rotated at a fast speed at start-up in order to build a desired pressure. Once the desired pressure is reached, then one of two actions can be taken. First, the outer stage drive motor 180 can be turned off so that the outer impeller stage rotates freely and the drive energy imposed on the outer stage is provided by a fluid coupling fluidic forces provided by the driven inner impeller stage 112. Under such an arrangement, the inner impeller stage 112 may be rotating at a first speed N1 while the outer stage may be rotating at a reduced, second rotational speed N2. Typically, N2 is approximately one-half the rotational speed of N1. Thus, the electric motor drive 180 is capable of being switched on for starting and then turned off for normal operation of the outer impeller stage 114. During low inner impeller stage drive speed operation, such as engine starting, the electric drive motor 180 that drives the outer impeller stage 114 builds the required system pressure and flow. Once sufficient engine speed is attained to permit the impeller stage to produce the required system pressure, the electric drive motor 180 may be switched off. Thereafter, the outer stage 114 is allowed to act as a free rotating disk, and driven only by the fluidic coupling provided by fluid rotation caused by the inner impeller stage 112 and thereby improves the operating efficiency of the pump 100.

[0029] In other instances, it may be desired to control the rotational speed of the outer stage 114 by using both the fluid coupling and the outer stage drive motor 180. In such instances, the outer impeller stage 114 is rotated faster or slower than the inner impeller stage, however, optimized pump performance can be controlled through selective, independent drive of the outer impeller stage.

[0030] By locating the outer impeller stage 114 in concentric relation with the inner impeller stage 112, the fluid is first pressurized by the inner impeller stage, exits outlet 118, and is fed to inlet of the radial passage 144 of the outer impeller stage. Upon exiting the outer impeller stage, the energized fluid enters the stationary diffuser and ultimately reaches the discharge or outlet of the fluid pump.

[0031] The concentric arrangement provides for a compact package of a high speed centrifugal pump that includes a start stage. In addition, by independently driving the inner and outer impeller stages, reduced impeller fluid friction drag due to a free rotating disk action during normal operation is achieved. Likewise, there is an increased ability to receive flow at the stationary radial diffuser and shape the diffuser pressure recovery characteristics due to lower outer stage rotational speed. As a result, pump performance can be optimized relative to the ratio of impeller drive speeds (i.e., N1 vs. N2). Further, pump performance can be optimized via the ratio of pressure rise from each impeller stage. All of this is achieved in a pump package volume that is minimized and a multi-stage pump that has a reduced weight while still incor-

porating a start stage.

[0032] The disclosure has been described with reference to the preferred embodiments. Modifications and alterations will occur to others upon reading and understanding this specification. It is intended to include all such modifications and alterations in so far as they come within the scope of the appended claims or the equivalents thereof.

Claims

1. A centrifugal pump assembly comprising:

a first pump stage;
a second pump stage independently rotatable relative to and disposed in concentric relation with the first pump stage; and
a drive assembly operatively associated with the first and second pump stages that rotates the first and second pump stages to a first rotational speed and then (a) turns off drives the first pump stage of the first rotational speed or (b) independently drives the first and second pump stages above the first rotational speed.

2. The centrifugal pump assembly of claim 1 wherein the second pump stage rotates freely independent of the first rotational speed.

3. The centrifugal pump assembly of claim 1 wherein the first pump stage is an inner impeller stage and the second pump stage is an outer impeller stage.

4. The centrifugal pump assembly of claim 1 wherein the drive assembly includes a main drive shaft connected to and selectively rotating the first pump stage.

5. The centrifugal pump assembly of claim 1 wherein the drive assembly includes a separate drive for rotating the second pump stage.

6. The centrifugal pump assembly of claim 5 wherein the separate drive is an electric motor drive.

7. The centrifugal pump assembly of claim 6 wherein the electric motor drive rotates the second pump stage at a different speed than the main drive shaft rotates the first pump stage.

8. A method of operating a centrifugal pump assembly comprising:

providing a first pump stage;
providing a second pump stage concentrically mounted around the first pump stage;
independently driving the first and second pump

stages; and

switching off the drive for the second pump stage above a preselected rotational speed.

9. The method of claim 8 further comprising allowing the second pump stage to rotate freely relative to the first pump stage above the preselected rotational speed.

10. The method of claim 8 further comprising driving the first and second pump stages at different speeds.

11. The method of claim 8 wherein the driving step includes using an electric motor drive for rotating the second pump stage.

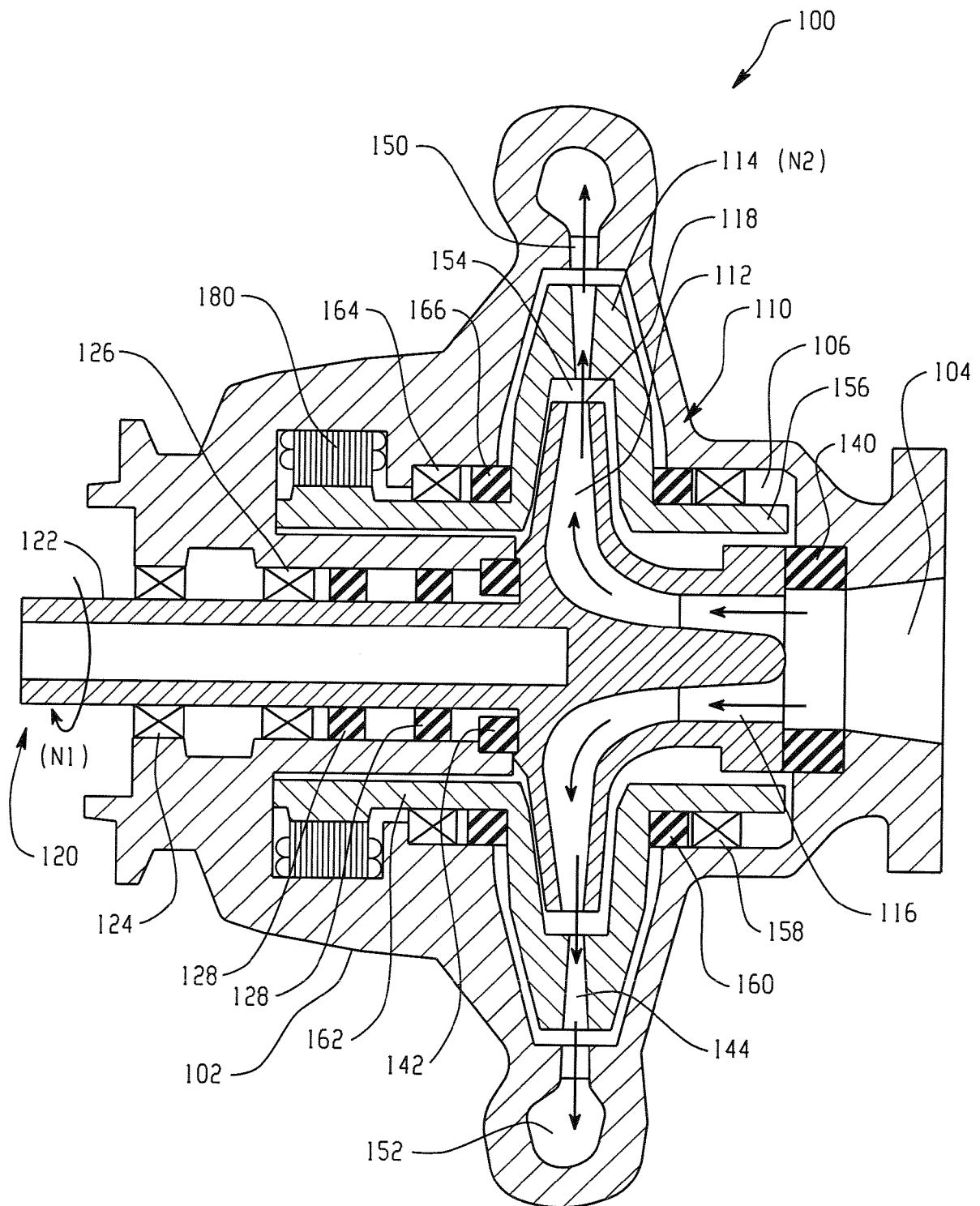


Fig. 1