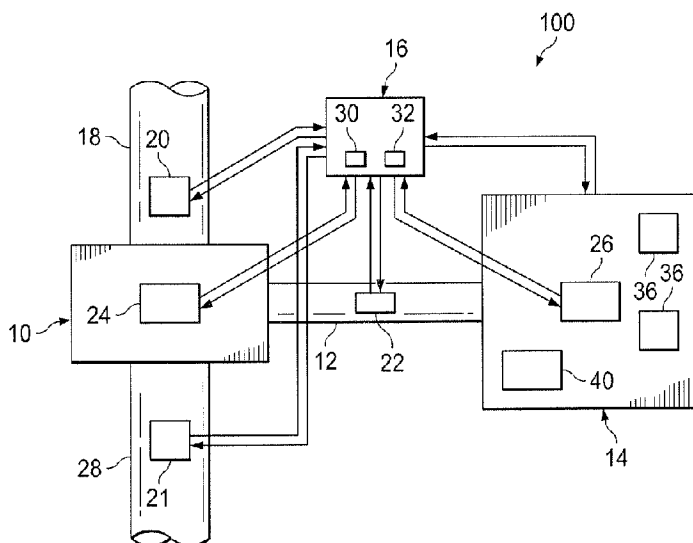




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(54) Title: SYSTEMS AND METHODS OF OPTIMIZED PUMP SPEED CONTROL TO REDUCE CAVITATION, PULSATION AND LOAD FLUCTUATION



(57) **Abrégé/Abstract:**

The speed of a pump may be controlled to reduce cavitation and to reduce flow and pressure fluctuation in the pumped fluid. A system for pumping a fluid may comprise a pump, a primary mover coupled to the pump, and a controller coupled to the primary mover wherein the controller is programmed to control the primary mover so as to optimize a characteristic of the system. Pumping a fluid may comprise providing a pumping apparatus that comprises a pump, a primary mover which actuates the pump, and a controller which sends commands to the primary mover. One or more characteristics of the pumping apparatus may be utilized to modify the speed of the pump.

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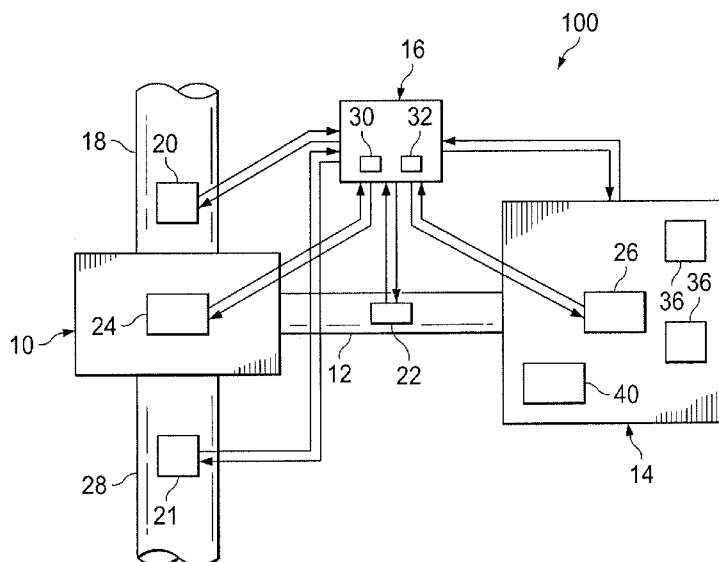


FIG. 1

(57) Abstract: The speed of a pump may be controlled to reduce cavitation and to reduce flow and pressure fluctuation in the pumped fluid. A system for pumping a fluid may comprise a pump, a primary mover coupled to the pump, and a controller coupled to the primary mover wherein the controller is programmed to control the primary mover so as to optimize a characteristic of the system. Pumping a fluid may comprise providing a pumping apparatus that comprises a pump, a primary mover which actuates the pump, and a controller which sends commands to the primary mover. One or more characteristics of the pumping apparatus may be utilized to modify the speed of the pump.

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SYSTEMS AND METHODS OF OPTIMIZED PUMP SPEED CONTROL TO REDUCE CAVITATION, PULSATION AND LOAD FLUCTUATION

TECHNICAL FIELD

5 The present disclosure generally relates to subterranean drilling operations, more particularly, to systems and methods of controlling pump speed to reduce cavitation and load fluctuation in the pumped fluids.

BACKGROUND

10 Hydrocarbons, such as oil and gas, are commonly obtained from subterranean formations that may be located onshore or offshore. The development of subterranean operations and the processes involved in removing hydrocarbons from a subterranean formation are complex. Typically, subterranean operations involve a number of different steps such as, for example, mixing and pumping fluids into a wellbore at a desired well site.

15 Cavitation, pulsation, and load fluctuation are common problems/faults encountered when pumping fluids. In particular, cavitation can cause accelerated wear and mechanical damage to pump components, couplings, gear trains, and drive motors. Cavitation and load fluctuation are often caused by the pulsation of the pumping apparatus. Cavitation is the formation of vapor bubbles in the inlet or the suction zone/stroke of the pump. This condition occurs when local pressure drops to below the vapor pressure of the liquid being pumped. These
20 vapor bubbles collapse or implode when they enter a high pressure zone (for example, at the discharge valve during the discharge/power stroke) of the pump causing erosion of or damage to pump components or both. If a pump runs for an extended period under cavitation conditions, permanent damage may occur to the pump structure and accelerated wear and deterioration of pump internal surfaces and seals may occur. Depending on the type of pump, other problems
25 may occur such as inlet or outlet blockage, leakage of air into the system due to faulty pump seals or valves, leaky or damaged valves, internal parts impacting the pump casing, etc. Consequently, a need exists for improved systems and methods for preventing cavitation, pulsation, and load fluctuation in pumps.

BRIEF DESCRIPTION OF THE DRAWINGS

5 For a more complete understanding of the present disclosure and its features and advantages, reference is now made to the following description, taken in conjunction with the accompanying drawing, in which:

FIG. 1 is a schematic view of the pumping apparatus in accordance with certain embodiments of the present disclosure.

10 FIG 2. is a schematic view of an exemplary fracturing apparatus in accordance with certain embodiments of the present disclosure.

While embodiments of this disclosure have been depicted, such embodiments do not imply a limitation on the disclosure, and no such limitation should be inferred. The subject matter disclosed is capable of considerable modification, alteration, and equivalents in form and
15 function, as will occur to those skilled in the pertinent art and having the benefit of this disclosure. The depicted and described embodiments of this disclosure are examples only, and not exhaustive of the scope of the disclosure.

DETAILED DESCRIPTION

5 Illustrative embodiments of the present disclosure are described in detail herein. In the interest of clarity, not all features of an actual implementation are described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation specific decisions must be made to achieve developers' specific goals, such as compliance with system related and business related constraints, which will vary from
10 one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of the present disclosure. Furthermore, in no way should the following examples be read to limit, or define, the scope of the disclosure.

The present disclosure relates to systems and methods for pumping fluids, more
15 particularly, to systems and method of controlling pump speed to reduce cavitation and load fluctuation in the pumped fluids.

Cavitation is often caused by the improperly configured rig-up jobs. A rig-up job may be considered improperly configured for any number of reasons. For example, a rig-up job is improperly configured when the hoses that connect the blender to the pumps and the hoses that
20 lead downhole from the pumps vary in length, number, or diameter. Cavitation caused by an improperly configured rig-up job is exacerbated by high pump speeds, which are often associated with well stimulation treatments and other downhole operations. Well stimulation treatments, such as fracturing or acidizing treatments, require high pump speeds in order to generate the requisite pressure to fracture or stimulate a subterranean formation. Furthermore,
25 the pumping of slurries in other subterranean operations requires relatively high pump speeds to ensure the particulates remain suspended.

Cavitation can be reduced by fluctuating the speed of the pump in a periodic manner such that the pump speed effectively prevents vapor bubbles in the pump's inlet from forming. A reduction in cavitation may be achieved by varying the speed of the engine or motor that
30 actuates the pump. In one or more embodiments, the engine or motor may be a diesel or other combustion engine, an electric motor, or any combination thereof. In one or more embodiments, an electric motor is used as more control over the variations in speed may be achieved. The engine or motor may be controlled by a controller, such as, an information handling system.

The present disclosure may be understood with reference to FIG. 1, where like numbers
35 are used to indicate like and corresponding parts. FIG. 1 is a schematic view of the pumping apparatus 100 in accordance with certain embodiments of the present disclosure. Pumping apparatus 100 may be located at a well surface, at a well site along with various types of drilling

5 or fracturing equipment (not expressly shown) or at any other location where an operation requires a pumping apparatus 100.

The pumping apparatus 100 comprises a pump 10 coupled to a primary mover 14 by a drive train 12. In certain embodiments, the pump 10 comprises a positive displacement pump. In certain embodiments, the primary mover 14 comprises a drive mechanism 40. Drive
10 mechanism 40 may comprise an internal combustion engine. In certain embodiments, the internal combustion engine may comprise a diesel engine. In certain embodiments, the drive mechanism 40 may comprise an electric motor. In certain embodiments the movement of the primary mover 14 actuates the movement of the pump 10. In certain embodiments, the primary mover 14 is coupled directly to the pump 10 and actuates pumping of pump 10 directly. In
15 certain embodiments, the primary mover 14 is coupled to the drive train 12 and actuates the pumping of pump 10 by actuating the movement of the drive train 12. In certain embodiments, the speed of the primary mover 14 determines the pumping speed of the pump 10. A person of skill in the art with the benefit of this disclosure would see that the speed at which the primary mover 14 operates may determine the rotational speed of pump 10. Furthermore, a person of
20 skill in the art with the benefit of this disclosure would appreciate that the primary mover 14 may be controlled to change the rotational speed of the pump 10 in any manner known in the art.

The pump 10 operates so as to pump fluid from an upstream portion of a fluid channel 28 to a downstream portion of a fluid channel 18. The fluid channels 18 and 28 may comprise hosing, piping, any kind of hosing or piping known in the art or any combination thereof. In one
25 or more embodiments, fluid channel 18 is downstream of a blender (not shown). In one or more embodiments, fluid channel 18 leads directly into the wellbore 60 as described in Figure 2. In one or more embodiments, fluid channel 18 couples to a manifold (not shown).

The pumping apparatus 100 further comprises a controller 16. The controller 16 is electronically coupled to the primary mover 14. The controller 16 may comprise a processor 30
30 and a memory 32 where the memory 32 comprises one or more instructions, such as a program, that when executed by the processor 30 control the primary mover 14. In one or more embodiments, the primary mover 14 may comprise a memory 34 and a receiver 36 such that the primary mover 14 may receive the one or more commands sent by the controller 16. The controller 16 may throttle the speed at which the primary mover 14 operates. Throttling the
35 speed of the primary mover 14 may cause the speed of the primary mover 14 and thus the pump 10 the primary mover 14 actuates to cyclically decrease and increase continuously.

Additionally, the controller 16 may be programmed to optimize one or more characteristics of the pumping apparatus 100. For example, for a given operation or

5 environment, one or more characteristics of the pumping apparatus 100 may be selected for optimization. In one or more embodiments, the controller 16 may calculate the speed at which the primary mover 14 operates such that the selected characteristic is optimized. Characteristics of the pumping apparatus 100 may include, but are not limited to, vibration of a component of the primary mover 14, torque or force of at least one component of the primary mover 14, linear
10 or angular displacement of at least one component of the primary mover 14, linear or angular velocity of at least one component of the primary mover 14, , linear or angular acceleration of at least one component of the primary mover 14, fuel or electrical power efficiency of the primary mover 14, emissions produced by the primary mover 14, vibration of the drivetrain 12, torque of the drive train 12, angular velocity of the drivetrain 12, angular acceleration of the drive train 12,
15 flow rate of the pump 10, inlet pressure of the pump 10, outlet pressure of the pump 10, vibration of the pump 10, force of the pump 10, torque of the pump 10, in linear or angular displacement of the pump 10, linear or angular velocity of the pump 10, linear or angular acceleration of the pump 10, or any other characteristic. In some embodiments, the calculated speed is based, at least in part, on one or more characteristics of the pumping apparatus 100. For example, in one
20 or more embodiments, the pump 10 may accelerate fluid according to a well-known function or functions such as slider-crank motion equations, fluid compression and bulk modulus relations, valve force-mass acceleration equations. The controller 16 may be programmed to control the primary mover 14 based on the well-known function to optimize the flow rate of the fluid through the pump 10. In one or more embodiments, this calculation is based, at least in part, on
25 the signals from one or more sensors discussed in greater detail below.

The pumping apparatus 100 may further comprise one or more sensors 26. Any of the one or more sensors 26 may be coupled to the controller 16. In one or more embodiments, one or more sensors 26 may be disposed within or coupled to the primary mover 14. The sensor 26 is coupled to the primary mover 14 such that the sensor 26 may monitor at least one characteristic
30 of the primary mover 14. For example, in one or more embodiments the sensor 26 may monitor at least one of the vibration of a component of the primary mover 14, the torque or force of at least one component of the primary mover 14, the linear displacement of at least one component of the primary mover 14, the linear or angular velocity of at least one component of the primary mover 14, the linear or angular acceleration of at least one component of the primary mover 14,
35 or any combination thereof. In one or more embodiments, sensor 26 may comprise a pressure sensor, a strain gauge, an accelerometer, a position sensor, a velocity sensor, an acoustic sensor, or any combination thereof.

5 In one or more embodiments, the sensor 26 may further communicate or transmit the information about the monitored characteristic to the controller 16 at regular intervals, timed intervals, intermittent intervals, predetermined intervals or at any other interval. In some embodiments, the information is communicated continuously. The controller 16 may modify the control signal sent to the primary mover 14 based, at least in part, on the information received
10 from sensor 26, such that the primary mover 14 operates to optimize any one or more characteristics of the pumping apparatus 100. In one or more embodiments, the sensor 26 monitors any one or more characteristics being optimized by the controller 16.

In one or more embodiments, the pumping apparatus 100 may comprise a sensor 22 wherein the sensor 22 is coupled to the controller 16 and the drive train 12. The sensor 22 is
15 coupled to the drive train 12 to monitor at least one characteristic of the drive train 12. For example, the sensor 22 may monitor at least one of the vibration of a component of the drive train 12, the torque or force of at least one component of the drive train 12, the linear displacement of at least one component of the drive train 12, the linear or angular velocity of at least one component of a drive train 12, the linear or angular acceleration of at least one
20 component of the drive train 12, or any combination thereof. In one or more embodiments, sensor 22 may comprise a pressure sensor, a strain gauge, an accelerometer, a position sensor, a velocity sensor, an acoustic sensor, or any combination thereof.

In one or more embodiments, the sensor 22 may further communicate the information about the characteristic to the controller 16 at regular intervals, timed intervals, intermittent
25 intervals, predetermined intervals or at any other interval. In one or more embodiments, the information is communicated continuously. The controller 16 may modify the control signal the control 16 sends to the primary mover 14 based on the information received from sensor 22, such that the primary mover 14 operates to optimize a characteristic of the pumping apparatus 100. In some embodiments, the characteristic sensor 22 monitors the same characteristic or a different
30 characteristic being optimized by the controller 16.

In some embodiments, the pumping apparatus 100 may comprise a sensor 24 wherein the sensor 24 is coupled to the controller 16 and the pump 10. The sensor 24 is coupled to the pump 10 such that it may monitor at least one characteristic of the pump 10. For example, the sensor 24 may monitor at least one of the vibration of a component of the pump 10, the torque or
35 force of at least one component of the pump 10, the linear displacement of at least one component of the pump 10, the linear or angular velocity of at least one component of a pump 10, the linear or angular acceleration of at least one component of the pump 10, fluid flow, pressure, or any combination thereof. In some embodiments, sensor 24 may comprise a strain

5 gauge, an accelerometer, a pressure sensor, a position sensor, a velocity sensor, an acoustic sensor, a flow meter, or any combination thereof.

In one or more embodiments, the sensor 24 may further communicate the information about the characteristic to the controller 16 at regular intervals, timed intervals, intermittent intervals, predetermined intervals or at any other interval. In one or more embodiments, the
10 information is communicated continuously. The controller 16 may modify the control signal the controller 16 sends to the primary mover 14 based on the information received from sensor 24, such that the primary mover 14 operates to optimize a characteristic of the pumping apparatus 100. In one or more embodiments, the characteristic sensor 24 monitors the same characteristic optimized or a different characteristic being by the controller 16.

15 In one or more embodiments, the downstream portion of a fluid 18 may comprise a sensor 20, wherein the sensor 20 is coupled to the controller 16. The sensor 20 monitors at least one characteristic of the downstream portion of the fluid channel 18. One or more characteristics monitored by sensor 20 may comprise at least one of the vibration of the downstream portion of a fluid channel, fluid flow, pressure, or any combination thereof. In one or more embodiments,
20 sensor 20 may comprise an accelerometer, a flow meter, a pressure sensor, or any combination thereof.

In one or more embodiments, the sensor 20 may further communicate the information about the characteristic to the controller 16 at regular intervals, timed intervals, intermittent intervals, predetermined intervals or at any other interval. In one or more embodiments, the
25 information is communicated continuously. The controller 16 may modify the control signal the controller 16 sends to the primary mover 14 based on the information received from sensor 20, such that the primary mover 14 operates to optimize a characteristic of the pumping apparatus 100. In one or more embodiments, the characteristic sensor 20 monitors the same characteristic optimized by the controller 16. For example, in certain embodiments, sensor 20 may monitor
30 any one or more characteristics including, but not limited to, the vibration of the downstream portion of the fluid channel 18, while the controller 16 commands the primary mover 14 to operate to optimize the flow rate of the fluid in fluid channel 18. In certain embodiments, the sensor 20 may monitor the vibration of the downstream portion of the fluid channel 18, while the controller 16 commands the primary mover 14 to operate to reduce the vibration of the pump 10.
35 In some embodiments, the sensor 20 monitors a different characteristic than the characteristic being optimized by controller 16.

In one or more embodiments, the upstream portion of a fluid channel 28 may comprise a sensor 21, wherein the sensor 21 is coupled to the controller 16. The sensor 21 monitors at

5 least one characteristic of the upstream portion of the fluid channel 28. One or more characteristics monitored by sensor 21 may comprise at least one of: the vibration of the upstream portion of a fluid channel, fluid flow, pressure, or any combination thereof. In one or more embodiments, sensor 21 may comprise an accelerometer, a flow meter, a pressure sensor, or any combination thereof.

10 In one or more embodiments, the sensor 21 may further communicate the information about the monitored characteristic to the controller 16 at regular intervals, timed intervals, intermittent intervals, predetermined intervals or at any other interval. In one or more embodiments, the information is communicated continuously. The controller 16 may modify the control signal the controller 16 sends to the primary mover 14 based on the information received
15 from sensor 21, such that the primary mover 14 operates to optimize a characteristic of the pumping apparatus 100. In one or more embodiments, the characteristic sensor 21 monitors the same characteristic optimized by the controller 16. For example, in certain embodiments, the characteristic sensor 21 may monitor the vibration of the upstream portion of the fluid channel 28, while the controller 16 commands the primary mover 14 to operate to optimize the flow rate
20 of the fluid in fluid channel 28. In certain embodiments, the sensor 21 may monitor the vibration of the upstream portion of the fluid channel 28, while the controller 16 commands the primary mover 14 to operate to reduce the vibration of the pump 10. In some embodiments, the sensor 21 monitors a different characteristic than the characteristic being optimized by controller 16.

Figure 2 shows the well 60 during an exemplary fracturing operation using the
25 pumping apparatus 100 in a portion of a subterranean formation of interest 102 surrounding a well bore 104. Apart from fracturing operations, the apparatus of Figure 2 may be used in a variety of different well stimulation treatments such as acidizing treatments. The well bore 104 extends from the surface 106, and the fracturing fluid 108 is applied to a portion of the subterranean formation 102 surrounding the horizontal portion of the well bore. Although
30 shown as vertical deviating to horizontal, the well bore 104 may include horizontal, vertical, slant, curved, and other types of well bore geometries and orientations, and the fracturing treatment may be applied to a subterranean zone surrounding any portion of the well bore. The well bore 104 can include a casing 110 that is cemented or otherwise secured to the well bore wall. The well bore 104 can be uncased or include uncased
35 sections. Perforations can be formed in the casing 110 to allow fracturing fluids and/or other materials to flow into the subterranean formation 102. In cased wells, perforations can be formed using shape charges, a perforating gun, hydro-jetting and/or other tools.

5 The well is shown with a work string 112 depending from the surface 106 into the well bore 104. The pump and blender system 50 is coupled a work string 112 to pump the fracturing fluid 108 into the well bore 104. The working string 112 may include coiled tubing, jointed pipe, and/or other structures that allow fluid to flow into the well bore 104. The working string 112 can include flow control devices, bypass valves, ports, and or
10 other tools or well devices that control a flow of fluid from the interior of the working string 112 into the subterranean zone 102. For example, the working string 112 may include ports adjacent the well bore wall to communicate the fracturing fluid 108 directly into the subterranean formation 102, and/or the working string 112 may include ports that are spaced apart from the well bore wall to communicate the fracturing fluid
15 108 into an annulus in the well bore between the working string 112 and the well bore wall.

 The working string 112 and/or the well bore 104 may include one or more sets of packers 114 that seal the annulus between the working string 112 and well bore 104 to define an interval of the well bore 104 into which the fracturing fluid 108 will be pumped. FIG. 2
20 shows two packers 114, one defining an uphole boundary of the interval and one defining the downhole end of the interval. When the fracturing fluid 108 is introduced into well bore 104 (for example, in Figure 2, the area of the well bore 104 between packers 114) at a sufficient hydraulic pressure, one or more fractures 116 may be created in the subterranean zone 102. The proppant particulates in the fracturing fluid 108 may enter the fractures 116 where they
25 may remain after the fracturing fluid flows out of the well bore. These proppant particulates may "prop" fractures 116 such that fluids may flow more freely through the fractures 116.

 An embodiment of the present disclosure is a system for pumping fluid comprising a pump, a primary mover coupled to the pump, and a controller coupled to the primary mover, wherein the controller is programmed to control the primary mover so as to optimize a first
30 characteristic of the system, wherein the controller commands the primary mover to throttle its speeds such that the primary mover's speed over time follows a cyclic or periodic function, for example, a sine function.

 Another embodiment of the present disclosure is a method for pumping a fluid comprising providing a pumping apparatus comprising a pump, a primary mover that actuates
35 the pump, and a controller comprising a processor and a memory device programmed to send commands to the primary mover; and using known characteristics of the pump to modify the commands sent to the primary mover such that a characteristic of the pumping apparatus is optimized.

Another embodiment of the present disclosure is a method for pumping a fluid comprising providing a pumping apparatus comprising a pump, a primary mover mechanically coupled to the pump by a drive train such that the primary mover actuates the pump, a controller that sends commands to the primary mover, and a sensor coupled to the controller; pumping the fluid downhole; monitoring a first characteristic of the pumping apparatus with the sensor, sending a signal to the controller indicative of the magnitude of the first characteristic being monitored by the sensor; determining an appropriate command signal to send to the primary mover to optimize a second characteristic of the pumping apparatus; and sending the appropriate command signal to the primary mover to optimize the second characteristic of the pumping apparatus.

Therefore, the present disclosure is well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the present disclosure may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee.

CLAIMS:

1. A system for pumping a fluid, comprising:
 - a pump;
 - a primary mover coupled to the pump;
 - a controller coupled to the primary mover, wherein the controller is configured to cause the speed of the primary mover to fluctuate cyclically as a function of a first characteristic of the system, the first characteristic indicative of cavitation, pulsation and/or load fluctuation in the fluid pumped by the pump; and
 - at least one sensor communicatively coupled to the controller.
2. The system of claim 1, wherein the sensor is configured to monitor a second characteristic of the system.
3. The system of claim 2, wherein the first characteristic and the second characteristic are the same.
4. The system of claim 2, wherein at least one of the first characteristic and second characteristic comprises a fluid pressure, a fluid flow rate, a vibration, a force, a torque, a linear displacement, an angular displacement, a linear velocity, an angular velocity, a linear acceleration, or an angular acceleration.
5. The system of claim 2, wherein the at least one sensor comprises at least one of a strain gauge, a flow meter, an accelerometer, a pressure sensor, a position sensor, a velocity sensor or an acoustic sensor.
6. The system of claim 1, wherein the primary mover comprises an electric motor.
7. The system of claim 1, wherein the primary mover comprises an internal combustion engine.

8. The system of claim 1, wherein the primary mover is coupled to the pump by a drivetrain.
9. A method for pumping a fluid, comprising:
 - providing a pumping apparatus, wherein the pumping apparatus comprises a pump, a primary mover, and a controller, wherein the controller comprises a processor and a memory device, wherein the processor is programmed to send one or more commands to the primary mover;
 - actuating, by the primary mover, the pump;
 - modifying at least one of the one or more commands based, at least in part, on one or more characteristics of the pumping apparatus, the one or more characteristics being indicative of cavitation, pulsation and/or load fluctuation in the fluid pumped by the pump; and
 - sending at least one of the one or more modified commands to the primary mover as a function of the at least one of the one or more characteristics of the pumping apparatus.
10. The method of claim 9, wherein at least one of the one or more characteristics of the pumping apparatus comprises a fluid pressure, a fluid flow rate, a vibration of an apparatus component, a force of a component of the pumping apparatus, a torque of the component, a linear displacement of the component, an angular displacement of the component, a linear velocity of the component, an angular velocity of the component, a linear acceleration of the component or an angular acceleration of the component.
11. The method of claim 9, wherein the pumping apparatus comprises an electric motor.
12. The method of claim 9, wherein the pumping apparatus comprises an internal combustion engine.
13. The method of claim 9, further comprising sending one or more command signals to the primary mover to control a rotational speed of the pump, wherein controlling the rotational speed of the pump comprises fluctuating the rotational speed cyclically as a function of the at least one of the one or more characteristics of the pumping apparatus.

14. A method for pumping a fluid in a well operation, comprising:
- providing a pumping apparatus comprising: a pump, a primary mover mechanically coupled to the pump by a drive train such that the primary mover actuates the pump, a controller that sends commands to the primary mover, and a sensor coupled to the controller;
 - pumping the fluid downhole;
 - monitoring a first characteristic of the pumping apparatus with the sensor;
 - sending a signal to the controller indicative of a magnitude of the first characteristic;
 - generating a command signal as a function of a second characteristic of the pumping apparatus; and
 - sending the command signal to the primary mover, wherein the command signal causes a speed of the primary mover to fluctuate cyclically such that a fluctuation of a pump speed mitigates formation of vapor bubbles in an inlet of the pump, thereby reducing cavitation.
15. The method of claim 14, wherein the first characteristic and the second characteristic are the same.
16. The method of claim 14, further comprising monitoring a third characteristic, wherein the third characteristic comprises a fluid pressure, a fluid flow rate, a vibration of a pumping apparatus component, a position, a velocity, an acoustic or any combination thereof.
17. The method of claim 14, wherein the pumping apparatus comprises an electric motor.
18. The method of claim 14, wherein the pumping apparatus comprises an internal combustion engine.
19. The method of claim 14, further comprising sending a command to the primary mover to fluctuate cyclically a rotational speed of the pump as a function of the second characteristic of the pumping apparatus.
20. The method of claim 14, wherein the first characteristic and the second characteristic are vibrations of the pumping apparatus.

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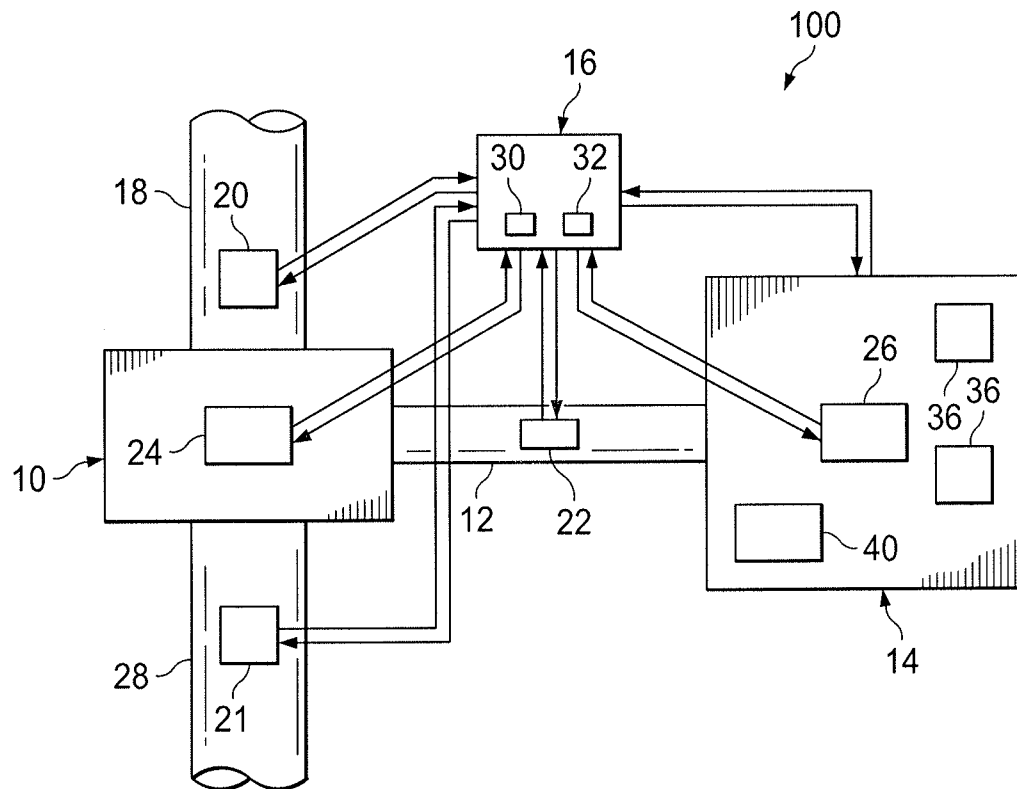


FIG. 1

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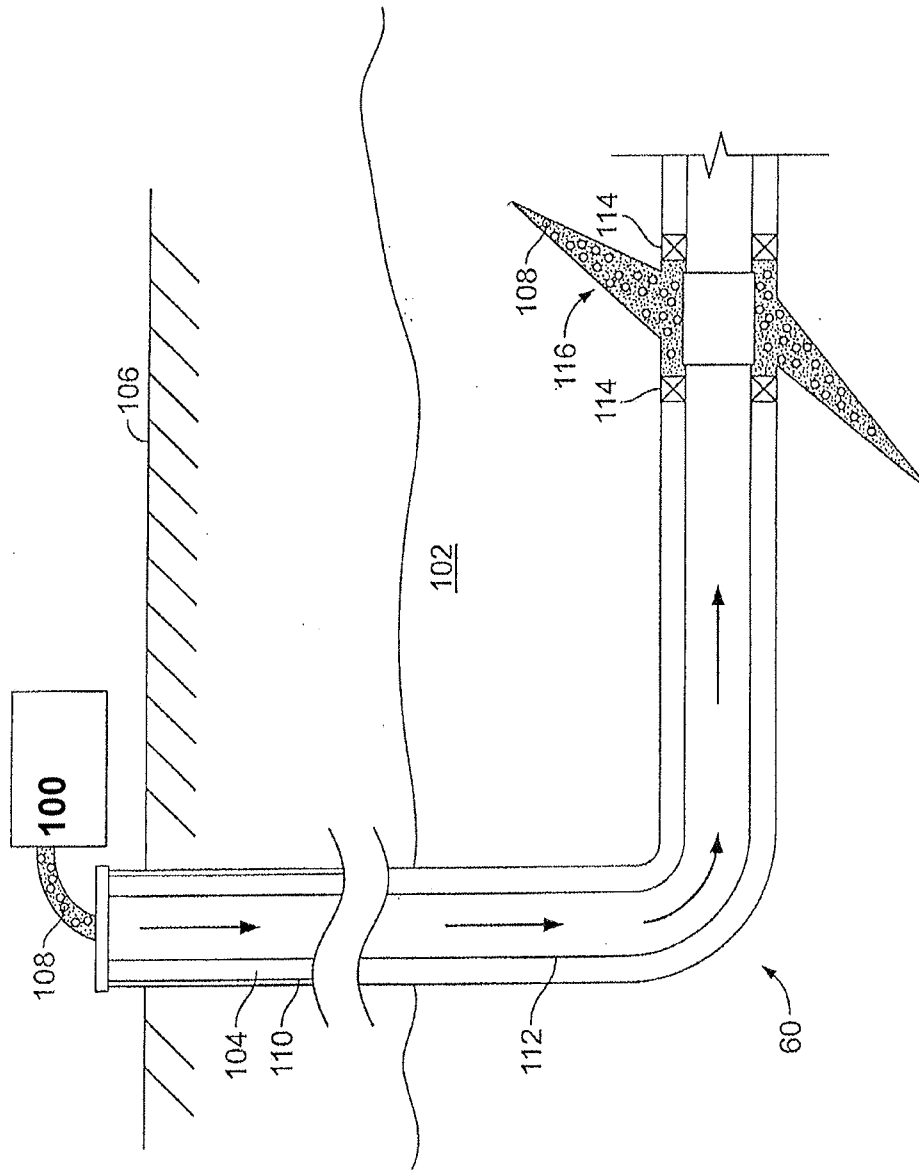


FIG.2

