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[Continued on next page]

(54) Title: SYSTEM AND METHOD TO POSITION VARIABLE DIFFUSER VANES IN A COMPRESSOR DEVICE

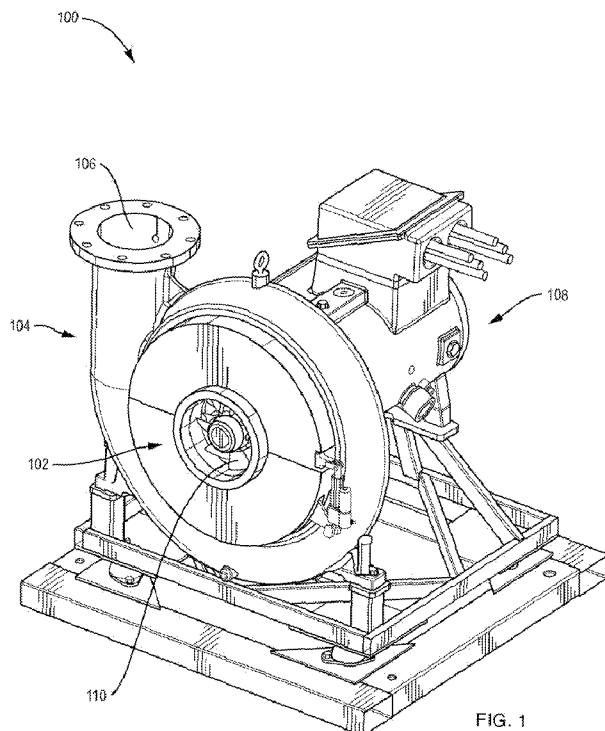


FIG. 1

(57) Abstract: Embodiments of a system and method can modify the position of diffuser vanes to improve performance of a compressor device, e.g., a centrifugal compressor. These embodiments include a feedback loop to manage the position of the diffuser vanes relative to one or more operating characteristics of an actuator that imparts movement to the diffuser vanes. In one embodiment, the system and method measure the operating characteristic for the actuator with the diffuser vanes at a first position and a second position. The system can compare values for the operating characteristics, wherein changes in the operating characteristic can identify other positions for the diffuser vanes to reduce input power the actuator consumes to move and/or maintain the position of the diffuser vanes. This feature can correlate with optimal performance of the compressor device and with peak compressor efficiency within the entire operating envelope of the compressor device.



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SYSTEM AND METHOD TO POSITION VARIABLE DIFFUSER VANES IN A COMPRESSOR DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of U.S. Patent Application Serial. No. 13/601,713, filed on August 21, 2012, and entitled “System and Method to Improve Performance of a Compressor Device Comprising Variable Diffuser Vanes.” The content of this application is incorporated by reference herein in its entirety.

BACKGROUND

[0002] The subject matter disclosed herein relates to compressor devices with particular discussion that concerns use of diffusers and diffuser vanes on a centrifugal compressor.

[0003] Centrifugal compressors and related compressor devices often use a diffuser assembly to convert kinetic energy of a working fluid into static pressure. In theory, the assemblies orient one or more diffuser vanes to slow the velocity of the working fluid through an expanding volume region. An example of the diffuser assembly arranges several diffuser vanes circumferentially about an impeller. The design (e.g., shapes and sizes) of the diffuser vanes, in combination with the orientation of the leading edge and the trailing edge of the diffuser vanes with respect to the flow of the working fluid, can determine how the diffuser vanes affix within the diffuser assembly.

[0004] In some compressor devices, the diffuser assembly incorporates variable diffuser vanes, which can move (e.g. rotate) during operation of the compressor device. This degree-of-freedom improves the design and flexibility of the compressor device to adapt to working conditions, e.g., changes in flow rate of the working fluid. For example, the variable diffuser vanes can move to change the orientation of the leading edge and the trailing edge to tune operation of the compressor device. Known designs for variable diffuser vanes rotate about an axis that resides in the lower half of the diffuser vanes, i.e., closer to the leading edge than the trailing edge.

BRIEF DESCRIPTION OF THE INVENTION

[0005] This disclosure presents embodiments of systems and methods that can modify orientation of variable diffuser vanes to improve performance of a centrifugal compressor and related compressor devices. The embodiments manage the position of the diffuser vanes relative

to operating characteristics associated with the diffuser assembly. In one embodiment, a controller couples with an actuator to collect data that relates to operation of the actuator to position the diffuser vane during operation of the compressor device. The data can reflect, for example, input power the actuator requires to move the diffuser vanes between a first position and a second position. The controller can compare the data to identify the change in the operating characteristics that occurs, if at all, when the diffuser vanes move between the first position and the second position. In one embodiment, the controller can generate an output in response to changes in the operating characteristic to move the diffuser vane to a third position. The controller can collect data about the operating characteristic at this third position and, subsequently, use the data to identify any change in operation of the actuator with the diffuser vanes in the third position. For example, pressure the working fluid imparts on the diffuser vanes in the third position may balance across the diffuser vanes, thus reducing the input power that the actuator requires to maintain the diffuser vanes in the third position. This reduction in input power can indicate that the diffuser vanes are in an optimal position for operation of the compressor devices. In some embodiments, the process of moving the diffuser vanes among positions continues to optimize performance of the compressor device, e.g., to reduce power consumption and to achieve and maintain peak compressor efficiency within the entire operating envelope for the compressor device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Reference is now made briefly to the accompanying drawings, in which:

[0007] FIG. 1 depicts a front, perspective view of an example of a compressor device;

[0008] FIG. 2 depicts a back, perspective view of the compressor device of FIG. 1;

[0009] FIG. 3 depicts a schematic diagram of an exemplary embodiment of a system for controlling operation of a compressor device, e.g., the compressor device of FIGS. 1 and 2;

[0010] FIG. 4 depicts a flow diagram of an exemplary embodiment of a method for operating a compressor device, e.g., the compressor device of FIGS. 1 and 2;

[0011] FIG. 5 depicts a top view of the exemplary diffuser vane in a first position and a second position for use in a compressor device, e.g., the compressor device of FIGS. 1 and 2;

[0012] FIG. 6 depicts a top view of the exemplary diffuser vane of FIG. 5 in a first position, a second position, and a third position; and

[0013] FIG. 7 depicts a high-level wiring schematic of an example of controller for use in a system, e.g., the system of FIG. 3.

[0014] Where applicable like reference characters designate identical or corresponding components and units throughout the several views, which are not to scale unless otherwise indicated.

DETAILED DESCRIPTION OF THE INVENTION

[0015] The discussion below describes embodiments of systems and methods to manage the position of diffuser vanes in a compressor device, e.g., a centrifugal compressor. These embodiments offer a robust and automated approach to tune operation of the compressor device. In one aspect, these embodiments use feedback from an actuator that couples with the diffuser vanes. The feedback can embody, for example, an input (e.g., a digital signal, an analog signal, etc.) that describes an operating characteristics of the actuator. The embodiments can use this operating characteristic to instruct the actuator to move and, in turn, manipulate the position of the diffuser vanes, thereby reducing power consumption of the compressor device.

[0016] Uses of the operating characteristic for the actuator can help to achieve and maintain peak efficiency within the entire operating envelope of the compressor device. As noted above, movement of the actuator can modify the orientation of the diffuser vanes, e.g., relative to the flow of a working fluid in the compressor device. The operating characteristics may, for example, reflect the input power (or other measure) that the actuator requires to perform this movement and/or to maintain the diffuser vane in a specified position relative to the flow of the working fluid. During operation, the input power may vary; typically in response to the change in the orientation of the diffuser vane relative to the flow of the working fluid. To achieve optimal performance of the compressor device, the diffuser vanes may assume a position in which the pressure of the working fluid balances about the surfaces of the diffuser vanes. In this position, the input power may have its lowest and/or smallest value, e.g., thus reflecting that the balancing of pressure of the working fluid and that the compressor devices is operating at peak (or near-peak) efficiency.

[0017] FIGS. 1 and 2 depict an example of a compressor device 100 that is configured to achieve optimal performance. In FIG. 1, the compressor device 100 has an inlet 102 and a volute 104 that forms an outlet 106. A drive unit 108 couples to an impeller 110. As best shown in FIG. 2, the compressor device 100 includes a diffuser assembly 112 with a plurality of diffuser vanes 114. The volute 104 forms an interior diffuser cavity that surrounds the diffuser vanes

114. The diffuser assembly 112 also includes an actuator 116, which couples to the diffuser vanes 114 to change the position of the diffuser vanes 114 as set forth herein.

[0018] During operation, the drive unit 108 rotates the impeller 110 to draw a working fluid (e.g., air) into the inlet 102. The impeller 110 compresses the working fluid. The compressed working fluid flows into the diffuser assembly 112, past the diffuser vanes 114, and through the remaining portion of the volute 104. In one embodiment, the compressor device 100 couples with industrial piping at the outlet 106 to expel the working fluid under pressure and/or with certain designated flow parameters as desired. For example, the compressor device 100 finds use in a variety of settings and industries including automotive industries, electronics industries, aerospace industries, oil and gas industries, power generation industries, petrochemical industries, and the like.

[0019] Examples of the actuator 116 can include linear actuators and like devices that create motion in a linear or straight-line. However, this disclosure does contemplate configurations of the diffuser assembly 112 that can utilize devices that create non-linear motion (e.g., rotary motion). One or more of the devices used for the actuator 116 may generate movement in response to electrical inputs (e.g., by way of an electric motor that drives a lead screw) as well as in response to a pneumatic input that can translate a piston/cylinder and/or like elements found in, for example, a pneumatic cylinder.

[0020] FIG. 3 illustrates a schematic diagram of a system 118 for controlling operation of the compressor device 100. The system 118 includes a controller 120 and a parameter sensor 122. The controller 120 communicates with the drive unit 108 to control rotation of the impeller 110. The controller 120 can also communicate with the diffuser assembly (e.g., diffuser assembly 112 of FIG. 2) by communicating with the actuator 116. This features can instruct operation of the actuator 116 to cause the diffuser vanes 114 to change position, e.g., from a first position to a second position. In one embodiment, the controller 120 (or one or more other devices in the system 118) can communicate via a network 124 with a peripheral device 126 (e.g., a display, a computer, smartphone, laptop, tablet, etc.) and/or an external server 128.

[0021] As also shown in FIG. 3, the system 118 includes a feedback loop 130 that couples the controller 120 with the actuator 116. The feedback loop 130 can conduct a signal 132 (also “an input 132”) (e.g., a digital signal, an analog signal, etc.) between the actuator 116 and the controller 120. Examples of the signal 132 can include data that reflects an operating characteristic for the actuator 116. This operating characteristic can identify one or more of input

power, power consumption, current draw, voltage, position, pneumatic pressure, as well as other conditions of the actuator 116 during operation of the compressor device 100.

[0022] The controller 120 can use this data to manage the position of the diffuser vane 114 in order to reduce power consumption and/or to optimize the operating efficiency of the compressor device 100. In one implementation, the controller 120 can instruct the actuator 116 to operate until the operating characteristic reaches a minimum value, e.g., which may reflect conditions in which the input power the actuator 116 utilizes is at a minimum to maintain the position of the diffuser vanes 114. This value may indicate, for example, that the diffuser vane 114 is in position to properly align leading edge and the trailing edge of the diffuser vane 114 with the flow of the working fluid. As noted above, this position can balance the pressure of the working fluid across the surfaces of the diffuser vane 114. The balance in the pressure can reduce the input power the actuator 116 needs to engage maintain the position of the diffuser vane 114.

[0023] Examples of the controller 120 include computers and computing devices with processors and memory that can store and execute certain executable instructions, software programs, and the like. The controller 120 can be a separate unit, e.g., part of a control unit that operates the compressor device 100 and other equipment. In other examples, the controller 120 integrates with the compressor device 100, e.g., as part of the hardware and/or software that operates the drive unit 108 and/or the actuator 116. In still other examples, the controller 120 can be located remote from the compressor device 100, e.g., in a separate location. The controller 120 can issue commands and instructions using wireless and wired communication, e.g., via the network 124.

[0024] The parameter sensor 122 monitors one or more operating parameters of the compressor device 100. Examples of these operating parameters include flow parameters (e.g., flow rate, flow velocity, static pressure, head pressure, etc.) and mechanical parameters (e.g., input power, current, voltage, torque, etc.), among others. The parameter sensor 122 can comprise one or more sensor devices that are sensitive to the operating parameters. These sensor devices can embody flow meters, pressure transducers, accelerometers, and like components. Such devices generate signals (also, “inputs”)(e.g., digital signals, analog signals, etc.), which include data that reflects a measured value for the corresponding operating parameter that the device is configured to measure.

[0025] The parameter sensor 122 may also couple with a shaft or other mechanism that transfers energy from the drive unit 108 to the impeller 110. When used in this manner, the parameter sensor 122 can measure several operating parameters (e.g., torque, angular velocity,

etc.) that define the operation of the drive unit 108 and/or the compressor device 102 in general. Other positions for the parameter sensor 122 include proximate the interior of the volute 104, proximate the outlet 106, proximate the diffuser assembly (e.g., diffuser assembly 112 of FIG. 2) as well as other positions to measure flow parameters as the working fluid moves through the compressor device 100. Moreover, the compressor device 100 may include circuitry to operate the drive unit 108 that includes certain configurations of elements (e.g., capacitors, resistors, transistors, etc.) to monitor inputs to the drive unit 108, e.g., current, voltage, power, etc.

[0026] Embodiments of the system 118 can implement sensor devices (e.g., parameter sensor 122) in various combinations to monitor and measure different operating parameters throughout the compressor device 100. For example, the system 118 may deploy a flow meter upstream of the diffuser vanes 114, a pressure sensor proximate the outlet 106 (FIGS. 1 and 2), and/or circuitry to monitor the amount of power the actuator 116 and/or the drive unit 108 uses during operation of the compressor device 100. The sensor devices provide signals to the controller 120. These signals transmit and/or include data and information that reflects the operation of the compressor device 100. The controller 120 can process the signals from the sensor devices to generate the outputs. These outputs can include data that reflects instructions for operation of one or more components that can configure the compressor device 100. As set forth more below, the outputs can include data that reflects instructions to change the position of the diffuser vanes 114, e.g., to instruct operation of the actuator 116 to change the orientation and/or position of one or more of the diffuser vanes 114. These instructions may, for example, cause the actuator 116 to move, which, in turn, moves (e.g., rotates) the diffuser vanes 114 through an angular offset from the first position to the second position.

[0027] FIG. 4 illustrates a flow diagram of an exemplary embodiment of a method 200 to operate a compressor device (e.g., compressor device 100 of FIGS. 1, 2, and 3). The method 200 includes, at step 202, receiving a first signal (also, “first input”) including data that reflects a first value for an operating characteristic of an actuator that couples with the diffuser vane in a first position and, at step 204, receiving a second signal (also, “second input”) including data that reflects a second value for the operating parameter of the actuator with the diffuser vane in a second position. The method 200 also includes, at step 206, comparing the first value and the second value. The method 200 further includes, at step 208, selecting an increment by which to move the diffuser vanes and, at step 210, generating an output that includes data to instruct the actuator to move the diffuser vane from the second position by the increment.

[0028] Collectively, one or more of the steps of the method 200 can be coded as one or more executable instructions (e.g., hardware, firmware, software, software programs, etc.). These executable instructions can be part of a computer-implemented method and/or program, which can be executed by a processor and/or processing device. Examples of the controller 120 (FIG. 3) can execute these executable instruction to generate certain outputs, e.g., a signal that encodes instructions to change the position of the diffuser vanes 114 (FIGS. 1, 2, and 3), a signal that encodes instructions to change operation of the drive unit 108 (FIGS. 1, 2, and 3), etc.

[0029] The steps for receiving a first signal (e.g., at step 202) and a second signal (e.g., a step 204) occur at different positions of the diffuser vanes 114 (FIGS. 2 and 3) to capture potential changes in the operating characteristic of the actuator 116 (FIGS. 1, 2, and 3). To illustrate, FIG. 5 shows an example of a diffuser vane 300 in a first position 302 and a second position, identified by phantom lines and the numeral 304. In one embodiment, the diffuser vane 300 changes between the first position 302 and the second position 304 in response to operation of the actuator 116 (FIGS. 1, 2, and 3).

[0030] The diffuser vane 300 has a vane body 306 with a leading edge 308 and a trailing edge 310. The diffuser vane 300 rotates about a rotation axis 312 to permit changes in the position of the trailing edge 310 relative to, in one example, the leading edge 308. This disclosure also contemplates construction of the diffuser vane 300 that would allow both the leading edge 308 and the trailing edge 310 to move about the rotation axis 312. For example, the rotation axis 312 can be positioned at various locations along the vane body 306, e.g., in locations spaced apart from the leading edge 308 and the trailing edge 310 along a chord length. The chord length measures the straight-line distance between the leading edge 308 and the trailing edge 310.

[0031] With respect to the configuration of the diffuser vane 300 in FIG. 5, rotation about the leading edge 308 is advantageous to accommodate the direction of the flow F, which can change orientation e.g., from a first flow direction F1 to a second flow direction F2. To this end, despite the relatively large angular displacement of the trailing edge 310 that occurs, the leading edge 308 is secured on the rotation axis 312 to limit changes to the position of the leading edge 308 as the trailing edge 310 moves between the first position 302 and the second position 304. This feature maintains the orientation of the leading edge 308 with the second flow F2 to reduce the likelihood of flow separation, while providing adequate adjustment of the trailing edge 310 to dictate changes in the performance, e.g., of the compressor device 100 (FIGS. 1, 2, and 3).

[0032] Communication of the first signal and the second signal can occur by way of wireless and/or wired communication protocols. In one implementation, systems can utilize these protocols to convey data to the controller 120 (FIG. 3) from the actuator 116 (FIGS. 1, 2, and 3) by way of the feedback loop 130 (FIG. 3) and/or between one or more of the parameter sensors 122 (FIG. 3) and the controller 120 (FIG. 3). The signal encodes information about the operating characteristics for the actuator 116 (FIGS. 1, 2, and 3). This data can include values (also “measured values”) that may reflect a determinant values (e.g., voltage level, current level, power, pressure, etc.) that defines one or more operating characteristics for the actuator 116 (FIGS. 1, 2, and 3) that is the subject of measurement. In one embodiment, the method 200 can include steps for receiving a plurality of signals from different sensor devices and for selecting one or more of the signals based on, for example, the type of information and data included in the signals. These features of the method 200 can permit the selection of particular information, e.g., flow rate of incoming working fluid upstream of the impeller 110 (FIG. 1) and/or the diffuser vanes 114 (FIGS. 1, 2, and 3), and/or combinations of information, e.g., flow rate of incoming working fluid upstream of the impeller 110 (FIG. 1) and/or the diffuser vanes 114 (FIGS. 1, 2, and 3), pressure at the outlet 106 (FIGS. 1 and 2), and input power of the actuator 116 (FIGS. 1, 2, and 3). These selections may be part of a user interface (e.g., a graphical user interface) that displays on one or more of the peripheral devices 126 (FIG. 3) or on other display equipment associated with the compressor device 100 (FIGS. 1, 2, and 3) and/or the system 118 (FIG. 3).

[0033] The steps for comparing the first value and the second value (e.g., a step 206) identifies the change or variation in the operating characteristic of the actuator 116 (FIGS. 1, 2, and 3) that corresponds with the change in position of the diffuser vane 300. These changes can, for example, increase and/or decrease the operating characteristic of the actuator 116. For purpose of one example, this comparison captures the relative change in input power (or power consumption) of the actuator 116 (FIGS. 1, 2, and 3) that is required to move the diffuser vane 300 from the first position 302 to the second position 304. In another example, the comparison can identify the input power of the actuator 116 (FIGS. 1, 2, and 3) to maintain the position of diffuser vane 300.

[0034] The steps for selecting an increment (e.g., at step 208) provides an incremental change in the position of the diffuser vanes 300. This incremental change moves the diffuser vanes 300 to another position, which in turn can change the value of the operating characteristic of the actuator 116 (FIGS. 1, 2, and 3). Examples of the incremental change can define both the amount of movement that will occur in the diffuser vane 300 as well as the direction of movement. FIG. 6, for example, illustrates the diffuser vane 300 in a third position 314, which

represents the position of the diffuser vane 300 offset from the second position 302 by an increment 316. As shown in the example of FIG. 6, the increment 316 defines several positional characteristics (e.g., an angular offset 318 and a direction 320) that determine the extent to which the position of the diffuser vane 300 changes relative to the second position 304. In one embodiment, the method 200 can include steps for comparing the relative values of the first value and the second value to assign the positional characteristics. For example, if the second value is less than the first value, then the method 200 can include steps for assigning the increment 316 a first set of positional characteristics that comprise a first direction and a first angular offset. On the other hand, if the second value is less than the first value, then the method 200 can include steps for assigning the increment 316 a second set of positional characteristics that comprise a second direction and a second angular offset. In one example, the first direction is different from the second direction (e.g., with respect of FIG. 6, the first direction is clockwise and the second direction is counter clockwise).

[0035] The amount of the angular offset can vary, both between the first angular offset and the second angular offset as well as based on the first value and the second value for the operating characteristic. For example, embodiments of the method 200 may include steps for calculating a variation value, which can have a value equal to the mathematical difference between the first value and the second value, and a step for comparing the variation value to a threshold criteria that can define the nominal values for the positional characteristics. In one example, if the variation value satisfies the threshold criteria, then the method 200 may include steps for assigning values to the increment 316. These values may decrease as the variation value decreases, e.g., as the operating characteristic of the actuator 116 (FIGS. 1, 2, and 3) converges to an optimal value (e.g., a minimum current level that indicates of the optimal position for the diffuser vanes).

[0036] The steps for generating an output (e.g., at step 210) can cause the actuator 116 (FIG. 1, 2, and 3) to move (also, actuator) to move the diffuser vane 300 between the second position 304 and the third position 314. The output can comprise any signal (e.g., analog and/or digital) that can include data that reflect instructions to operate a device. In the examples herein, the output can cause the actuator 116 (FIGS. 1, 2, and 3) to move between a first actuated position and a second actuated position, which can facilitate movement either directly and/or indirectly of the diffuser vanes (e.g., diffuser vanes 114 of FIGS. 2 and 3 and/or diffuser vane 300 of FIGS. 5 and 6) among and between one or more of the first position 302, the second position 304, and the third position 314.

[0037] In view of the foregoing discussion of the method 200, this disclosure contemplates embodiments in which the method 200 embodies an iterative and/or multi-operational technique to focus and optimize operation, e.g., of the compressor device 100 (FIGS. 1, 2, and 3). To this end, the method 200 may include one or more steps for resetting and or initializing one or more values for the operating characteristic for the actuator 116 (FIGS. 1, 2, and 3) and the positional characteristics. This feature prepares the methodology to accept additional data and/or to operate in a manner that promotes incremental changes in the position of the diffuser vanes (e.g., diffuser vanes 114 of FIGS. 1, 2, and 3 and diffuser vane 300 of FIGS. 5 and 6). For example, in one embodiment, on a second “pass” through the method 200, the first value from the operating parameter may be assigned the second value and, in turn, the second value may comprise a new value that identifies the operating value that occurs after the diffuser vane changes from the second position to the third position. In this way, the method 200 can compare at least one previous value to a new value for purposes of iterating the methodology to an optimum solution. For purposes of such an example, it may be unnecessary to receive and/or decode both the first signal (e.g., at step 202), but rather supplement the steps of the method 200 with one or more steps for assigning the first value with the second value, initializing the second value, and continuing on to receiving the second signal (e.g., at step 204).

[0038] FIG. 7 depicts a schematic diagram that presents, at a high level, a wiring schematic for a controller 400 that can process data (e.g., signals) to generate an output that instructs operation of a compressor device (e.g., compressor device 100 of FIGS. 1, 2, and 3). The controller 400 can be incorporated as part of a compressor device to provide an integrated and effective stand-alone system. In other alternatives, the controller 400 can remain separate and/or as part of a control system, which can also monitor various operations of the compressor device as well as the systems coupled thereto.

[0039] In one embodiment, the controller 400 includes a processor 402, memory 404, and control circuitry 406. Busses 408 couple the components of the controller 400 together to permit the exchange of signals, data, and information from one component of the controller 400 to another. In one example, the control circuitry 406 includes sensor driver circuitry 410 which couples with a parameter sensor 412 (e.g., parameter sensor 122 of FIG. 3) and motor drive circuitry 414 that couples with a drive unit 416 (e.g., e.g. drive unit 108 of FIGS. 1, 2, and 3). The control circuitry 406 also includes an actuator drive circuitry 418, which couples with an actuator 420 (e.g., actuators 116 of FIGS. 1, 2, and 3), and a radio circuitry 422 that couples to a radio 424, e.g., a device that operates in accordance with one or more of the wireless and/or wired protocols for sending and/or receiving electronic messages to and from a peripheral device

426 (e.g., a smartphone). As also shown in FIG. 7, memory 404 can include one or more software programs 428 in the form of software and/or firmware, each of which can comprise one or more executable instructions configured to be executed by the processor 402.

[0040] This configuration of components can dictate operation of the controller 400 to analyze data, e.g., information included in the signals from parameter sensor 412, the drive unit 414, and the actuator 420 to identify appropriate changes to the diffuser vanes and/or other changes to other operating properties (e.g., motor speed) of the compressor device. For example, the controller 400 can provide signals (or inputs or outputs) to speed up and slow down the drive unit 416, to instruct the actuator 420 to move to change the diffuser vanes from the first position to the second position, and/or actuate other devices that change the operation of the compressor device (e.g., compressor device 100 of FIGS. 1, 2, and 3).

[0041] The controller 400 and its constructive components can communicate amongst themselves and/or with other circuits (and/or devices), which execute high-level logic functions, algorithms, as well as executable instructions (e.g., firmware instructions, software instructions, software programs, etc.). Exemplary circuits of this type include discrete elements such as resistors, transistors, diodes, switches, and capacitors. Examples of the processor 402 include microprocessors and other logic devices such as field programmable gate arrays ("FPGAs") and application specific integrated circuits ("ASICs"). Although all of the discrete elements, circuits, and devices function individually in a manner that is generally understood by those artisans that have ordinary skill in the electrical arts, it is their combination and integration into functional electrical groups and circuits that generally provide for the concepts that are disclosed and described herein.

[0042] The structure of the components in the controller 400 can permit certain determinations as to selected configuration and desired operating characteristics that an end user convey via the graphical user interface or that are retrieved or need to be retrieved by the device. For example, the electrical circuits of the controller 400 can physically manifest theoretical analysis and logical operations and/or can replicate in physical form an algorithm, a comparative analysis, and/or a decisional logic tree, each of which operates to assign the output and/or a value to the output that correctly reflects one or more of the nature, content, and origin of the changes that occur and that are reflected by the inputs to the controller 400 as provided by the corresponding control circuitry, e.g., in the control circuitry 406.

[0043] In one embodiment, the processor 402 is a central processing unit (CPU) such as an ASIC and/or an FPGA that is configured to instruct and/or control operation one or more devices.

This processor can also include state machine circuitry or other suitable components capable of controlling operation of the components as described herein. The memory 404 includes volatile and non-volatile memory and can store executable instructions in the form of and/or including software (or firmware) instructions and configuration settings. Each of the control circuitry 406 can embody stand-alone devices such as solid-state devices. Examples of these devices can mount to substrates such as printed-circuit boards and semiconductors, which can accommodate various components including the processor 402, the memory 404, and other related circuitry to facilitate operation of the controller 400. In other embodiments, the memory 404 and processor 402 are remote from one another, e.g., the memory 404 is part of a server, computer, and/or computing device, as well as part of a cloud computing network. In either this remote configuration, or local configuration as shown in FIG. 7, the processor 402 can have access to executable instruction that are stored on memory and configured to be executed by the processor 404.

[0044] Moreover, although FIG. 7 shows the processor 402, the memory 404, and the components of the control circuitry 406 as discrete circuitry and combinations of discrete components, this need not be the case. For example, one or more of these components can comprise a single integrated circuit (IC) or other component. As another example, the processor 402 can include internal program memory such as RAM and/or ROM. Similarly, any one or more of functions of these components can be distributed across additional components (e.g., multiple processors or other components).

[0045] Further, as will be appreciated by one skilled in the art and contemplated herein, aspects of the present disclosure may be embodied as a system, method, computer-implemented method, and/or computer program product. Accordingly, aspects of the present disclosure may take the form of an entirely hardware embodiment, an entirely software embodiment (including one or more of firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a "circuit," "module" or "system." Furthermore, aspects of the present disclosure may take the form of a computer program product embodied in one or more computer readable medium(s) having computer readable program code and/or executable instructions embodied thereon.

[0046] Any combination of one or more computer readable medium(s) may be utilized. The computer readable medium may be a non-transitory computer readable signal medium or a non-transitory computer readable storage medium. Examples of a computer readable storage medium include an electronic, magnetic, electromagnetic, and/or semiconductor system, apparatus, or

device, or any suitable combination of the foregoing. More specific examples (a non-exhaustive list) of the computer readable storage medium would include the following: an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a computer readable storage medium may be any tangible medium that can contain, or store a program for use by or in connection with an instruction execution system, apparatus, or device.

[0047] Program code embodied on a computer readable medium may be transmitted using any appropriate medium, including but not limited to wireless, wireline, optical fiber cable, RF, etc., or any suitable combination of the foregoing. This program code may be written in any combination of one or more programming languages, including an object oriented programming language and conventional procedural programming languages. The program code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

[0048] The executable or computer program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus. The computer program instructions may also be stored in and/or on a computer readable medium that can direct a computer, other programmable data processing apparatus, or other devices to function in a particular manner.

[0049] Accordingly, a technical effect of embodiments of the systems and methods disclosed herein is to monitor the operation of the actuator to position the diffuser vanes in locations at which, in one example, the compressor device consumes the least amount of power.

[0050] As used herein, an element or function recited in the singular and proceeded with the word "a" or "an" should be understood as not excluding plural said elements or functions, unless such exclusion is explicitly recited. Furthermore, references to "one embodiment" of the claimed

invention should not be interpreted as excluding the existence of additional embodiments that also incorporate the recited features.

[0051] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

CLAIMS

What is claimed is:

1. A system, comprising:

a compressor device comprising an impeller, a diffuser vane in flow connection with the impeller, and an actuator coupled with the diffuser vane; and

a controller coupled to the compressor device, the controller comprising a processor having access to executable instructions stored on memory and configured to be executed by the processor, the executable instructions comprising instructions for:

receiving a first input comprising data for a first value of an operating characteristic for the actuator with the diffuser vane in a first position;

receiving a second input comprising data for a second value of the operating characteristic for the actuator with the diffuser vane in a second position;

comparing the first value and the second value;

selecting an increment by which to move the diffuser vane from the second position, the increment defining the relative position of the second value with respect to the first value; and

generating an output comprising data to instruct the actuator to move the diffuser vane from the second position by the increment.

2. The system of claim 1, wherein the operating characteristic identifies input power to the actuator.

3. The system of claim 1, wherein the operating characteristic correlates with flow characteristics about the diffuser vane.

4. The system of claim 1, wherein the actuator comprises a linear actuator.

5. The system of claim 4, wherein the linear actuator is configured to operate in response to an electrical input.

6. The system of claim 4, wherein the linear actuator is configured to operate in response to a pneumatic input.

7. The system of claim 1, wherein the executable instruction comprise instructions for determining an inlet flow value upstream of the impeller and setting the first position to correspond with the inlet flow value.

8. The system of claim 7, further comprising a flow meter disposed upstream of the impeller, the flow meter providing a third input that comprises data that reflects the inlet flow value, wherein the executable instruction comprise instructions for receiving the third input and instructing the actuator to move the diffuser vanes to the first position.

9. The system of claim 1, wherein the increment changes the position of the diffuser vane in a first direction if the second value is larger than the first value, wherein the increment changes the position of the diffuser vane in a second direction if the second value is smaller than the first value, and wherein the first direction is different from the second direction.

10. The system of claim 1, wherein the executable instructions comprise instructions for comparing the second value to a threshold criteria, wherein the threshold criteria defines a maximum value for the operating parameter and a minimum value for the operating parameter, and wherein the increment changes the position of the diffuser vane if the second value is equal to or greater than the maximum value and equal to or less than the minimum value.

11. The system of claim 1, wherein the diffuser vane has a leading edge and a trailing edge, and wherein the diffuser vane rotates about an axis proximate the leading edge.

12. The system of claim 1, wherein the increment defines an angular offset of the diffuser vane from the second position.

13. A compressor device, comprising:

a drive unit;

an impeller coupled to the drive unit;

a diffuser assembly in flow connection with the impeller, the diffuser assembly comprising a diffuser vane

an actuator coupled to the diffuser vane and configured to move the diffuser vane; and

a controller coupled with the actuator, the controller comprising a processor with access to executable instructions configured to be executed by the processor and stored on memory, the executable instructions comprising instructions for:

receiving a first input with data that relates to a first value for an operating characteristic for the actuator with the diffuser vane in a first position;

receiving a second input with data that relates to a second value for the operating characteristic for actuator with the diffuser vane in a second position;

comparing the first value and the second value;

selecting an increment by which to move the diffuser vane from the second position, the increment defining the relative position of the second value with respect to the first value; and

generating an output comprising data to instruct the actuator to move the diffuser vane from the second position by the increment.

14. The compressor device of claim 13, further comprising a parameter sensor coupled with the controller, wherein the parameter sensor is in position to measure flow of a working fluid.

15. The compressor device of claim 14, wherein the parameter sensor measures input power to drive the actuator.

16. The compressor device of claim 15, wherein the actuator comprises a pneumatic cylinder.

17. The compressor device of claim 15, wherein the actuator comprises a motor to generate movement of the diffuser vane from the second position.

18. The compressor device of claim 13, wherein the diffuser vane leading edge, a trailing edge, and a rotation axis proximate the leading edge, and wherein the trailing edge rotates about the leading edge when moving from the first position and the second position.

19. A computer program product for improving efficiency of a compressor device, the computer program product comprising a computer readable storage medium having executable

instructions embodied therein, wherein the executable instructions comprise one or more executable instructions for:

receiving a first input with data that relates to a first value for an operating characteristic for an actuator coupled with a diffuser vane in a first position;

receiving a second input with data that relates to a second value for the operating characteristic for the actuator with the diffuser vane in a second position;

comparing the first value and the second value;

selecting an increment by which to move the diffuser vane from the second position, the increment defining the relative position of the second value with respect to the first value; and

generating an output comprising data to instruct the actuator to move the diffuser vane from the second position by the increment.

20. The computer program product of claim 19, wherein the executable instructions comprise instructions for comparing the second value to a threshold criteria, wherein the threshold criteria defines a maximum value for the operating parameter and a minimum value for the operating parameter, and wherein the increment changes the position of the diffuser vane if the second value is equal to or greater than the maximum value and equal to or less than the minimum value.

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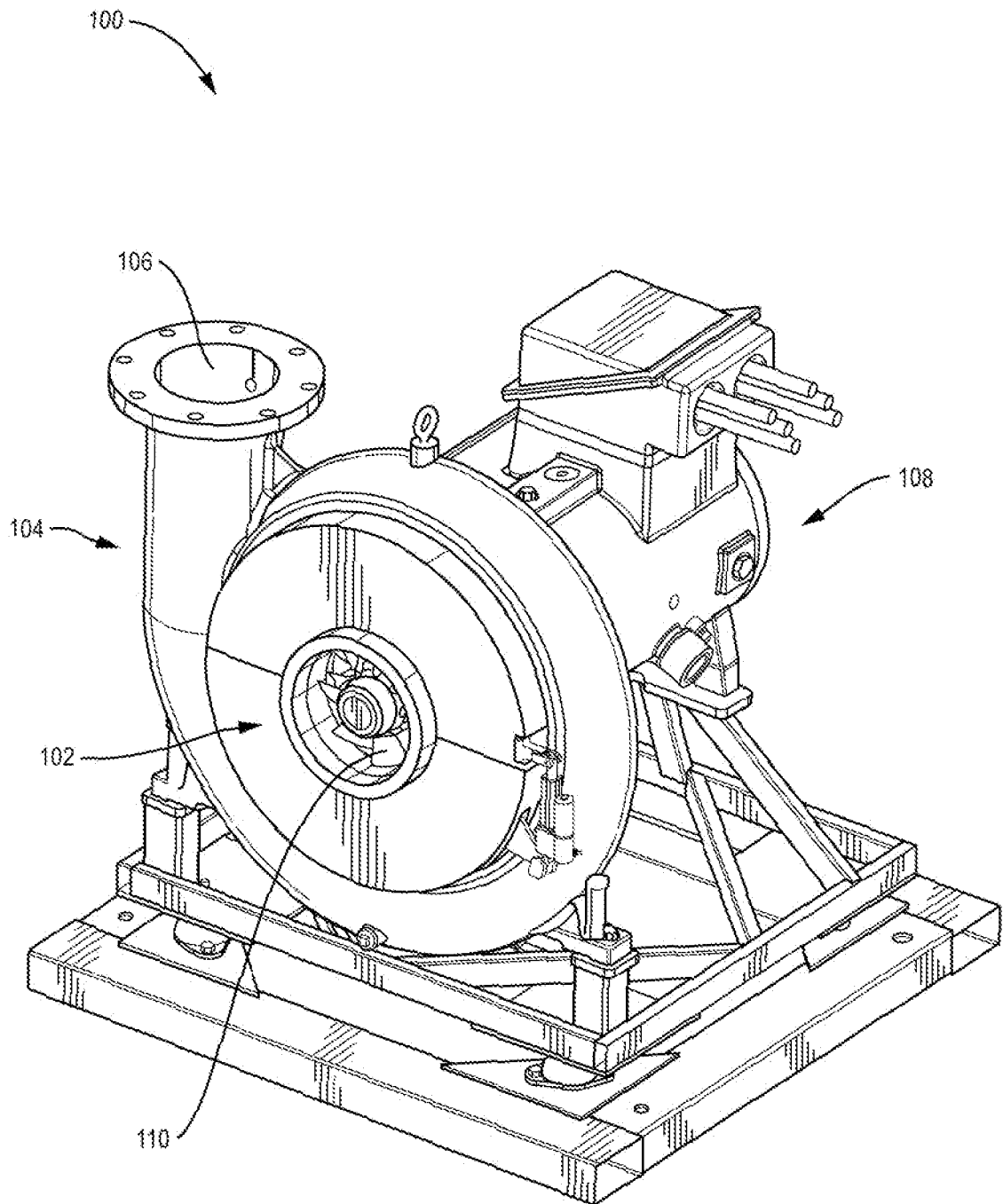


FIG. 1

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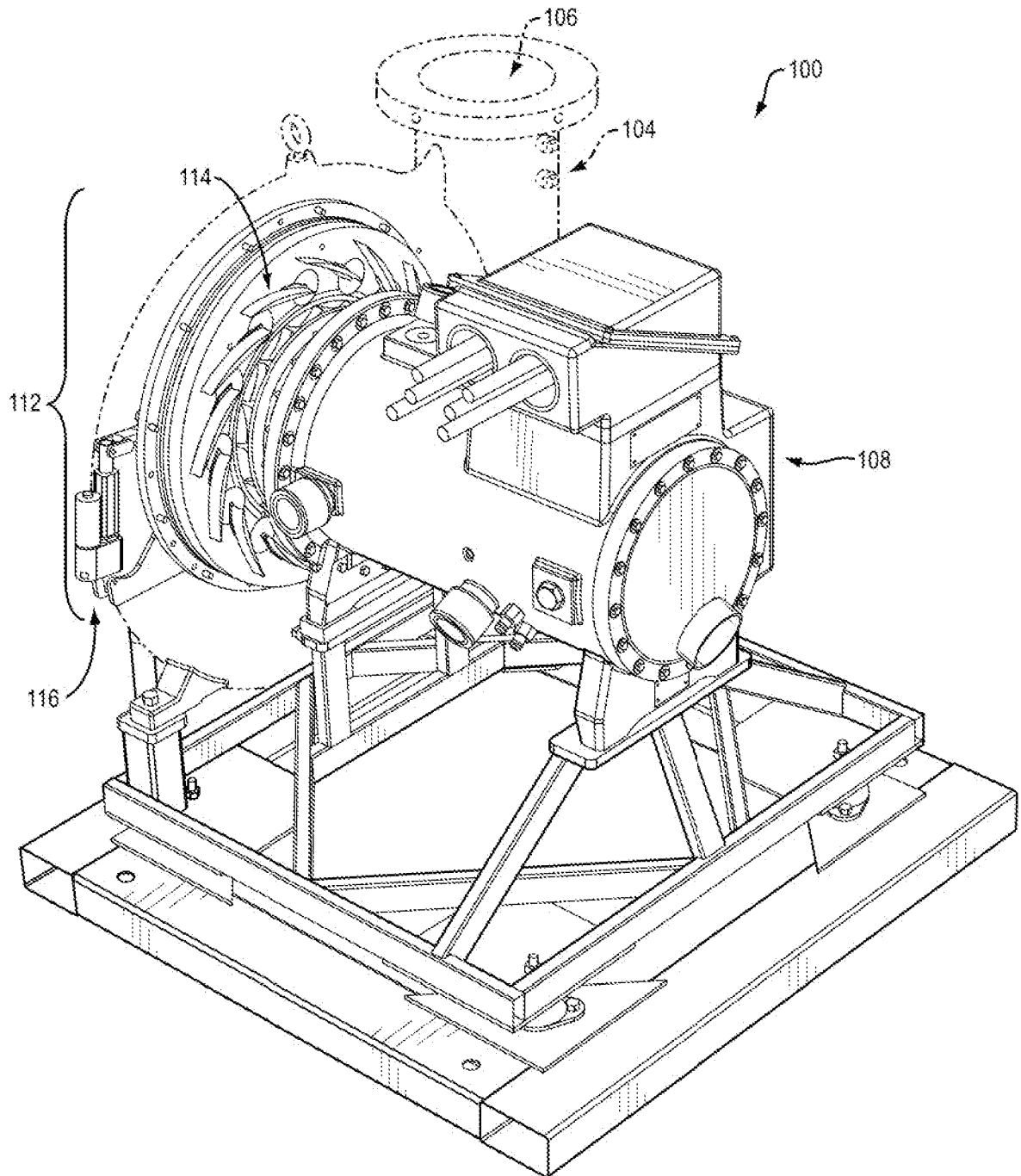


FIG. 2

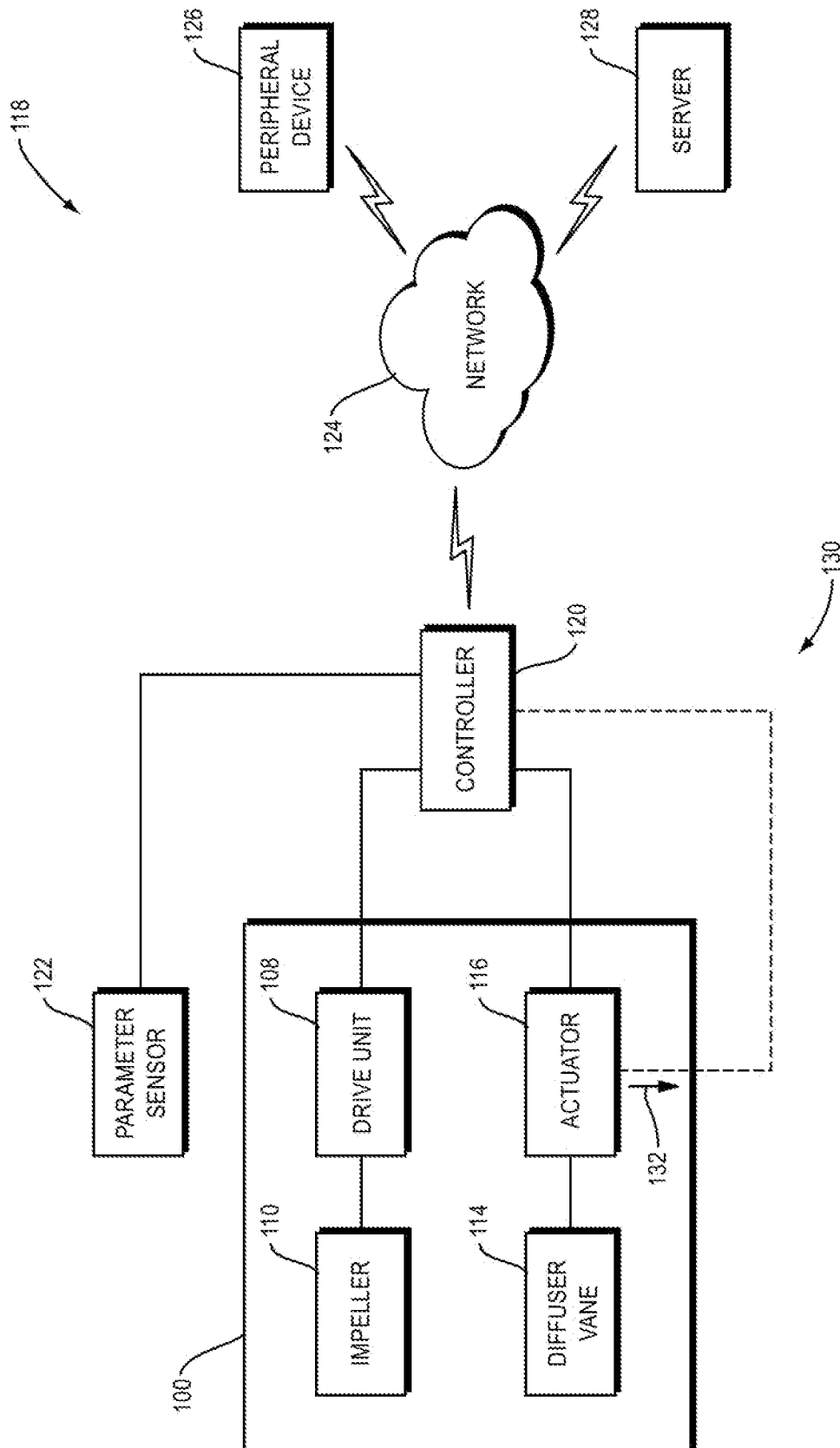


FIG. 3

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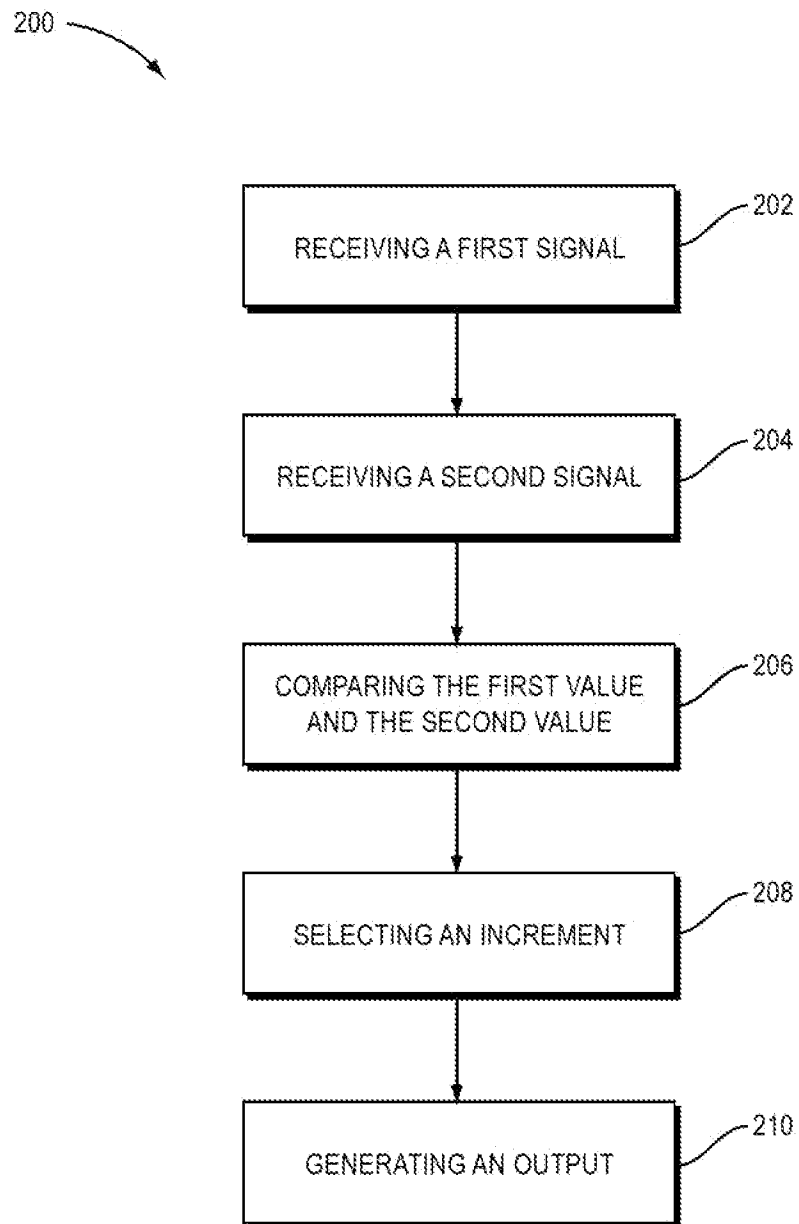


FIG. 4

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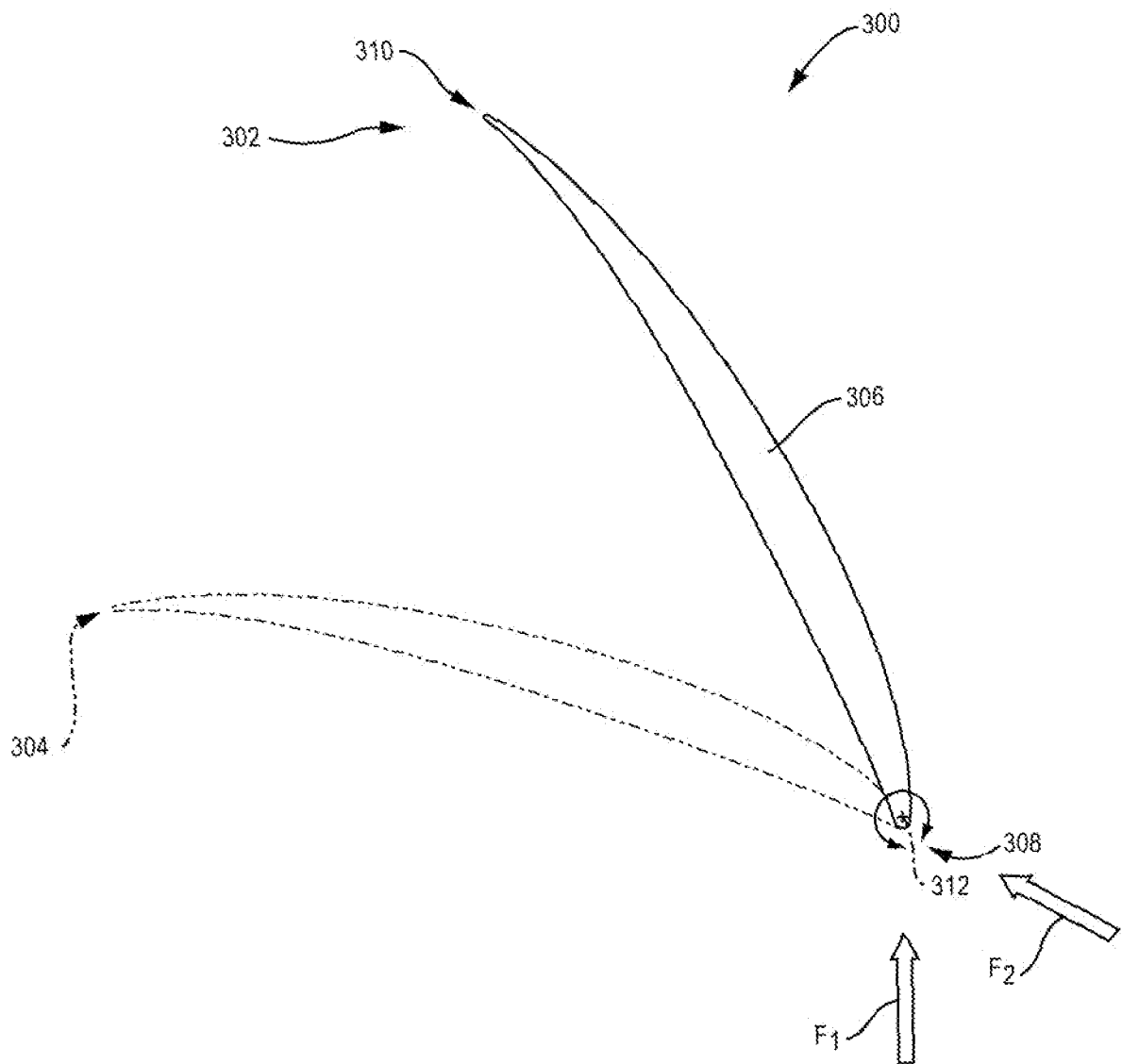


FIG. 5

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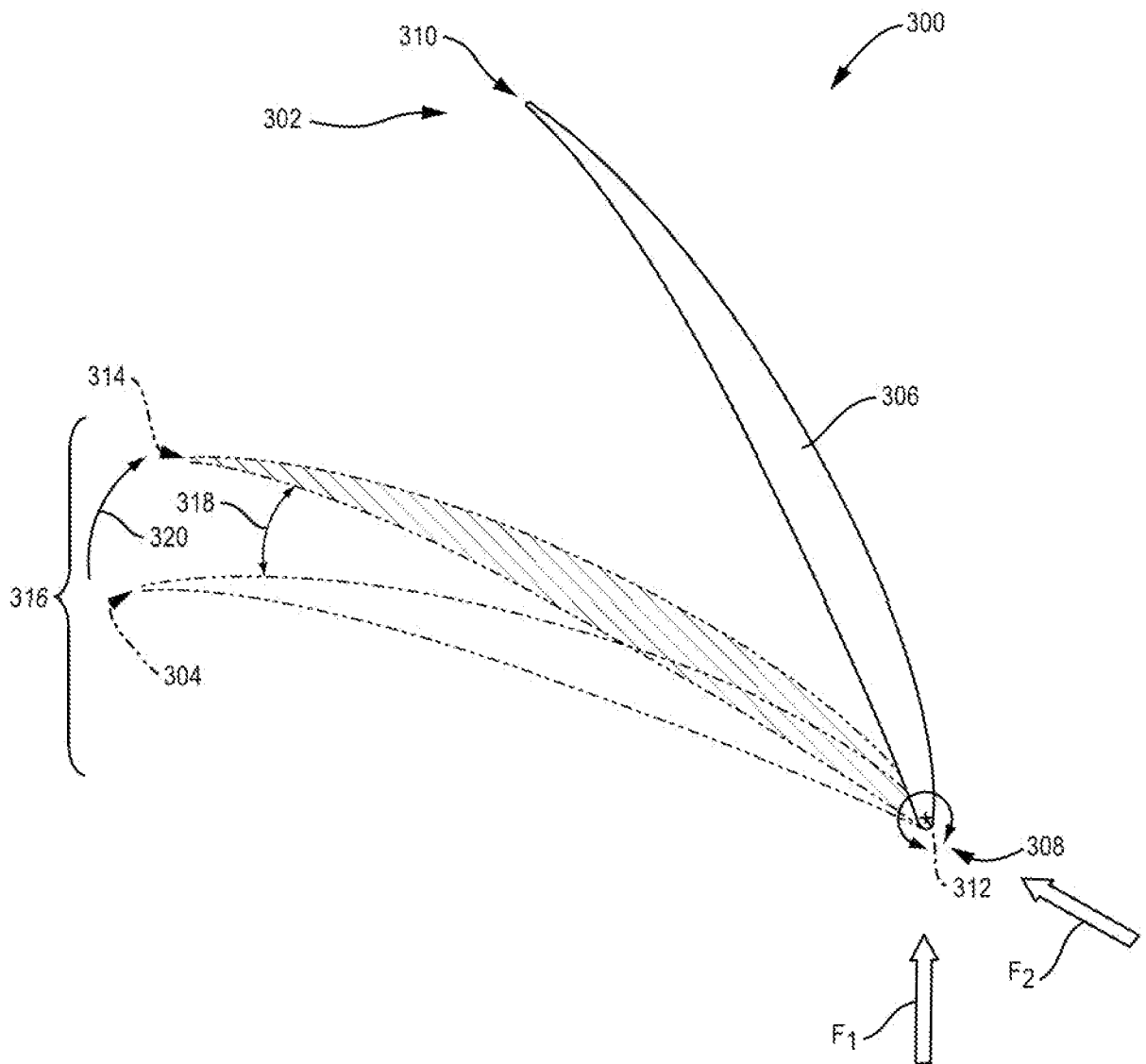


FIG. 6

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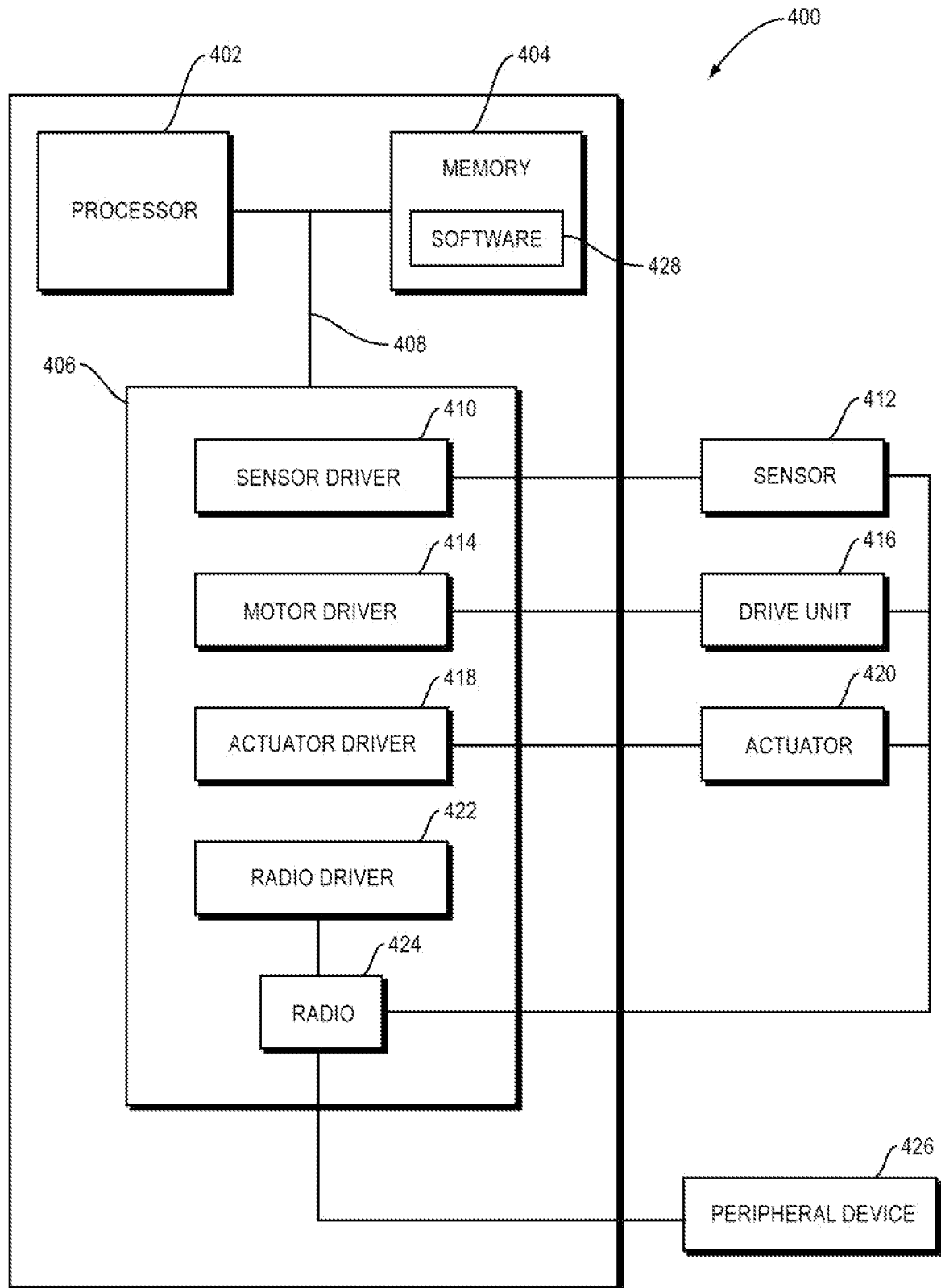


FIG. 7