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- **Ball, Michael**
Greenville, SC South Carolina 29615 (US)
- **Bowling, Patrick C.**
Atlanta, GA Georgia 30339 (US)
- **Pasupuleti, Mahesh**
560066 Bangalore (IN)
- **Pistner, Alexander James**
Atlanta, GA Georgia 30339 (US)

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(71) Applicant: **General Electric Company**
Schenectady, New York 12345 (US)

(74) Representative: **Cleary, Fidelma**
GPO Europe
GE International Inc.
The Ark
201 Talgarth Road
Hammersmith
London W6 8BJ (GB)

(72) Inventors:
• **Hemadrihotla, Venkata Ramana**
560066 Bangalore (IN)

(54) Tip Shroud Monitoring System, Method, and Controller

(57) A tip shroud (26) of a bladed rotor (20) can be monitored for integrity using a sensor (110) configured to detect the tip shroud (26). A signal from the sensor (110) can be monitored and if the magnitude of the signal changes, such as beyond a defined amount, an indication of possible damage can be made. A baseline sensed pattern for a revolution of the tip shroud (26) can be compared to an operation sensed pattern for a subsequent revolution, and the indication of damage can be made if there is more than the defined amount and/or percentage of difference between the patterns.

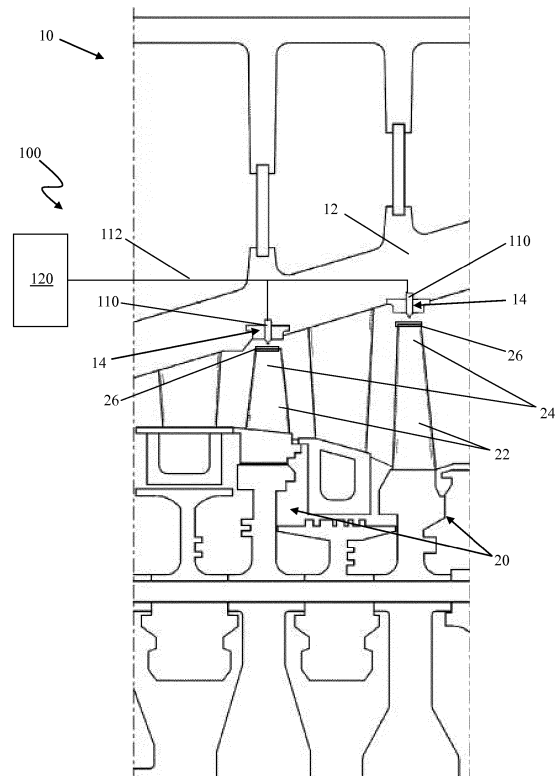


FIG. 2

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Description

BACKGROUND OF THE INVENTION

[0001] The invention relates generally to rotating machinery, such as gas and/or steam turbines. More particularly, the disclosure relates to the monitoring of integrity of a tip shroud of a rotor in a rotating machine.

[0002] Rotating machinery, such as gas and steam turbines, are used in many applications. Particularly in gas and steam turbines, rotors including a plurality of blades can be used to induce rotation of a shaft responsive to motion of a fluid and/or to cause motion of a fluid responsive to rotation of a shaft. To increase blade efficiency, improve structural integrity, and for any other suitable reason, many rotors include tip shrouds. A typical tip shroud can include mutually engaging, substantially identical blocks or plates formed and/or mounted on tips of rotor blades. Once assembled, the engaging blocks or plates can form a substantially continuous outer surface of a tip shroud.

[0003] A typical tip shroud can include one or more features to reduce flow around a rotor. For example, a tip shroud can include a circumferential rib or the like placed in close proximity to a stationary part of the machine in which the rotor operates, such as a housing. Clearance between the rib and the stationary part must be assured, and many systems exist to monitor and/or adjust clearance in such arrangements. However, occasionally a portion of a tip shroud can become damaged, such as from metal fatigue, which can result in a gap in the tip shroud. For example, a piece of a block or plate of the tip shroud can fall off and/or shift out of alignment, a portion of the tip shroud can deflect in undesirable ways, and/or other types of undesirable effects can occur. Clearance monitoring and/or adjusting systems do not account for such effects.

BRIEF DESCRIPTION OF THE INVENTION

[0004] The invention resides in a tip shroud monitoring system including a sensor responsive to a tip shroud of a rotor and a control system configured to receive a signal from the sensor. The control system can also be configured to monitor the signal from the sensor, to compare a value of a characteristic of the signal to a reference value of the characteristic, and to indicate possible tip shroud damage responsive to an amount of change in the value of the characteristic of the signal exceeding a defined amount of allowable change.

[0005] In another aspect, the invention resides in a method for monitoring a tip shroud of a rotor. A signal indicative of a presence of the tip shroud can be received and a value of a characteristic of the signal can be monitored. An amount of change in the value can be determined and compared to a defined amount of allowable change. Possible damage to the tip shroud can be indicated responsive to an amount of change exceeding a

defined amount of allowable change.

[0006] In yet another aspect, the invention resides in a machine having a rotor mounted for rotation relative to another part of the machine, the rotor including a tip shroud, a tip shroud monitoring controller. The controller can be configured for receiving a signal from a sensor configured to detect the tip shroud. The signal can be monitored by the controller, and the controller can compare and determine a difference between a value of a characteristic of the signal and a reference value. The controller can indicate possible tip shroud damage responsive to the difference exceeding a defined amount.

[0007] Other aspects of the invention provide methods of using and generating each of the embodiments described herein, which include and/or implement some or all of the actions described herein. The illustrative aspects of the invention are designed to solve one or more of the problems herein described and/or one or more other problems not discussed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] These and other features of the disclosure will be more readily understood from the following detailed description of the various aspects of the invention taken in conjunction with the accompanying drawings that depict various aspects of the invention.

FIG. 1 shows a schematic cross sectional diagram of a turbomachine or rotating machine, such as a gas turbine, in which embodiments of the invention disclosed herein may be used.

FIG. 2 shows a schematic diagram of an example of a tip shroud monitoring system that may include embodiments of the invention disclosed herein.

FIG. 3 shows a schematic representation of a baseline sensed pattern of a tip shroud monitoring system according to embodiments of the invention disclosed herein.

FIG. 4 shows a schematic representation of a deviating operation sensed pattern of a tip shroud monitoring system according to embodiments of the invention disclosed herein.

FIG. 5 is a schematic flow diagram of an example of a tip shroud monitoring system operation method according to embodiments of the invention disclosed herein.

FIG. 6 is a schematic flow diagram of an example of a tip shroud monitoring system operation method according to embodiments of the invention disclosed herein.

FIG. 7 is a schematic flow diagram of an example of

a tip shroud monitoring system operation method according to embodiments of the invention disclosed herein.

FIG. 8 shows a schematic block diagram of a computing environment for implementing a tip shroud monitoring system operation method and/or computer program product according to embodiments of the invention disclosed herein.

[0009] It is noted that the drawings may not be to scale. The drawings are intended to depict only typical aspects of the invention, and therefore should not be considered as limiting the scope of the invention. In the drawings, like numbering represents like elements between the drawings. The detailed description explains embodiments of the invention, together with advantages and features, by way of example with reference to the drawings.

DETAILED DESCRIPTION OF THE INVENTION

[0010] As used herein, "rotor" means a component of a machine configured to rotate relative to another component of the machine. For example, a rotor can include a plurality of blades mounted on a hub or a shaft, each blade having an airfoil cross section, and the hub or shaft being mounted for rotation relative to a housing or another part of a machine in which the rotor is used, as might be found in a turbomachine. Fluid passing over the blades can induce rotation of the hub or shaft, and rotation of the hub or shaft can induce motion and/or compression and/or expansion of a fluid in which the blades are immersed.

[0011] In addition, as used herein, "tip shroud" means a substantially continuous, annular body formed by blocks or plates on the tips of blades of a rotor. For example, each blade tip can bear a block or plate configured to engage and/or interlock with adjacent, substantially identical blocks or plates of adjacent blades. The engaged and/or interlocked blocks or plates thus form a tip shroud.

[0012] As described herein, a tip shroud monitoring system can include one or more sensors monitoring one or more substantially circumferential surfaces in a rotating machine, such as a tip shroud of a rotor in a turbine. Each sensor can send a signal to a control system that can monitor the signal(s) and indicate possible damage to a respective tip shroud if a value of a characteristic, such as magnitude, of the signal changes, such as by more than a threshold amount or percentage. The control system can determine a baseline sensed pattern from each signal, such as by storing a first series of values of the signal for a revolution of the tip shroud. The control system can then monitor each signal so that if the signal deviates from the baseline sensed pattern, such as by more than the defined amount, an indication of possible damage to the surface can be made. An operational sensed pattern can be determined, such as by storing a

second series of values of the signal for a subsequent rotation of the tip shroud, each of the second series of values corresponding to a respective one of the first series of values. The control system can compare the baseline sensed pattern to the operation sensed pattern for point-to-point correlation during monitoring, and if any pair of values differs by more than the defined amount, an indication of possible damage can be made. The baseline sensed pattern can be an initial operation sensed pattern, a previous operation sensed pattern, an average of operation sensed patterns, or other combination thereof as may be suitable and/or desired. For example, a current operation sensed pattern can replace the baseline sensed pattern and a new operation sensed pattern can be determined by storing another series of values for another rotation of the tip shroud.

[0013] As seen in FIG. 1, a machine 10 with which embodiments of the invention disclosed herein can take the form of a turbomachine, such as a gas turbine, though machine 10 can be any suitable rotating machine, as should be understood by those skilled in the art. The dashed circle identified as A in FIG. 1 indicates an area that is shown in an enlarged view in FIG. 2.

[0014] As seen in FIG. 2, an exemplary tip shroud monitoring system 100 can be deployed in a turbomachine 10 that has a casing or housing 12 and a mounting hole 14. One or more rotors 20 can be included in turbomachine 10 and arranged to rotate within casing 12 in response to fluid flowing over blades 22. Alternatively, blades 22 can induce motion in the fluid and/or compress and/or expand the fluid responsive to rotation of a rotor 20. Thus, while the particular section shown in FIG. 2 is of a turbine rotor, embodiments can be used with rotors of turbines or impellers as may be suitable and/or desired. Blades 22 of a rotor 20 can include tips 24 that including blocks or plates that engage the blocks or plates of adjacent tips 24 to form a tip shroud 26 of the respective rotor 20. Each tip shroud 26 can be a substantially circumferential and/or substantially continuous body in embodiments.

[0015] A tip shroud monitoring system 100 according to embodiments can include a sensor 110 mounted in hole 14 and arranged to sense or otherwise respond to a respective tip shroud 26. A control system 120, including a computing device, such as a controller, can be in communication with sensor(s) 110 so as to receive an output signal of each sensor 110. Control system 120 can communicate with sensor(s) 110 wirelessly or via line(s) 112, which can be electrical conductor, fiber optic cable, and/or other types of line(s) as may be appropriate and/or desired. Sensor(s) 110 can include any type of sensor that can produce a signal responsive to a suitable object being in range of the sensor, particularly a sensor that can produce a substantially continuous signal as an undamaged surface of a tip shroud passes it. For example, sensor(s) 110 can include capacitance sensors, optical sensors, magnetic sensors, and/or any other type of sensor as may be suitable and/or desired.

[0016] Control system 120 can be configured to monitor tip shroud(s) 26 by monitoring signal(s) from sensor(s) 110 and to indicate possible damage to a tip shroud 26 responsive to a change in a respective signal. In embodiments, control system 120 can compare a value of a characteristic of the respective signal to a reference value, such as a previous value of the characteristic. In addition, control system 120 can determine a difference between the current value of the characteristic and the reference value, which difference can represent an amount of change between the reference value and the current value of the characteristic. Embodiments can indicate possible damage when a signal changes by more than a defined amount of allowable change, which could indicate displacement and/or breakage of a portion of the respective tip shroud 26. The defined amount can, for example, be an allowable difference, an allowable percentage difference, or another suitable quantity and can be based on one or more factors, including manufacturing tolerances, typical operational deflection of a tip shroud, an operating condition, and/or any other factors as may be appropriate and/or desired.

[0017] In other embodiments, control system 120 can define a baseline sensed pattern 130 for each monitored tip shroud 26 over a revolution of the respective tip shroud 26, a schematic graphical depiction of which is shown in FIG. 3. Baseline sensed pattern 130 can, in embodiments, represent a value of a signal from sensor 110 (FIG. 2) over a period of time or over a revolution of tip shroud 26 (FIG. 2). For example, control system 120 (FIG. 2) can determine baseline sensed pattern 130 by storing a first series of values of a characteristic of the signal, such as in a memory or other storage device, for a revolution of tip shroud 26 (FIG. 2) in an undamaged condition. The number of values used in the first series of values can be chosen according to a size, speed, and/or a number of blades of rotor 20 (FIG. 2), and/or any other parameters as may be suitable and/or desired. First and second defined amounts 132, 134 of allowable change or deviation from baseline sensed pattern 130 can be employed for respective first and second directions of deviation from baseline sensed pattern 130 to establish respective first and second boundary curves 136, 138. During operation, if a value of the characteristic of the signal from a respective sensor 110 deviates by more than first defined amount 132 in the first direction, effectively passing beyond first boundary curve 136, then control system 120 (FIG. 2) can indicate that the respective tip shroud 26 (FIG. 2) may be damaged. Likewise, if a value of the characteristic of the signal from a respective sensor 110 (FIG. 2) deviates by more than second defined amount 134 in the second direction, effectively passing beyond second boundary curve 138, then control system 120 (FIG. 2) can indicate that the respective tip shroud 26 (FIG. 2) may be damaged. First and second defined amounts 132, 134 can be equal in embodiments, but can be different if behavior of the monitored surface or tip shroud is different in the first and second directions

during operation, or for any other reason as may be suitable and/or desired.

[0018] FIG. 4 shows a schematic graphical representation of the signal or output 140 of a sensor 110 (FIG. 2) over a revolution of a respective tip shroud 26 (FIG. 2) in which deviations have occurred. As shown, a first deviation 142 can be allowed as not indicative of possible damage since it lies within first and second boundary curves 136, 138 and has thus not deviated from baseline sensed pattern 130 by more than either of first and second defined amounts 132, 134. However, second deviation 144 is more pronounced, deviating beyond first defined amount 132, and thus can indicate possible damage. Control system 120 (FIG. 2) therefore would not indicate possible damage responsive to first deviation 142 in embodiments using defined amount(s) 132, 134, but would indicate possible damage responsive to second deviation 144. In embodiments not including allowable defined amount(s) of deviation, then both first and second deviations 142, 144 would result in control system 120 (FIG. 2) indicating possible damage to the respective tip shroud 26 (FIG. 2).

[0019] In additional embodiments, output 140 can represent an operation sensed pattern that can be compared to baseline sensed pattern 130. For example, control system 120 (FIG. 2) can store a second series of values of the characteristic of the signal from the respective sensor 110 (FIG. 2) for a subsequent revolution of tip shroud 26 (FIG. 2), establishing an operation sensed pattern. Each value of the second series of values can correspond to a respective one of the first series of values, thereby enabling point to point correlation of the operation sensed pattern and the baseline sensed pattern. By comparing the operation sensed pattern to the baseline sensed pattern, an amount of change for each corresponding pair of values can be determined. If the change in any corresponding pair of values exceeds the defined amount and/or a respective one of the first and second defined amounts 132, 134, an indication of possible damage can be made by control system 120 (FIG. 2). It should be noted that an indication of possible damage could be made if the change were greater than or equal to the defined amount(s) in embodiments.

[0020] FIG. 5 is a schematic flow diagram of an exemplary tip shroud monitoring method 200 that can be implemented by control system 120 (FIG. 2). In this first example, one or more sensor signals can be received and/or monitored (block 210), such as by controller 120 (FIG. 2). The signal(s) can be checked for a change in a value of a characteristic of the signal (block 220), such as by comparing the value to a reference value and/or to a previous value of the characteristic. If the value is unchanged, monitoring of the signal(s) can continue (block 210), but if the value has changed, an indication of possible tip shroud damage can be made (block 230). In addition, as described above, embodiments can include a defined amount of allowable change by which the signal(s) can change without indicating damage. To

this end, when a value of a respective signal changes, embodiments can determine whether the change is greater than the defined amount (block 222), such as by comparing the value to a reference value and/or determining a difference between the value and the reference value. If change exceeds the defined amount of allowable change, then an indication of possible tip shroud can be made (block 230), but if the change is less than or equal to the defined amount, then monitoring of the signal(s) can continue (block 210). Further, embodiments can take some action (block 232), such as initiate a shutdown of the machine in which the monitored tip shroud operates, responsive to an indication of possible tip shroud damage. A loop may be performed including receiving/monitoring the signal(s) (block 210), checking for a change in a signal value (block 220), and returning to receiving/monitoring the signal(s) (block 210) if there is no change in a signal value or if a change is not greater than the defined amount (block 222) and repeating the loop. As noted above, additional embodiments can determine whether the change in a value of a signal is greater than or equal to the defined amount in block 222.

[0021] Another example of a tip shroud monitoring method 200 according to embodiments, which includes that shown in FIG. 5 with additional steps, is shown in FIG. 6. In this example, after an initial receiving and/or monitoring of the signal(s) (block 210), a baseline sensed pattern is determined (block 212). The defined amount of change/deviation can be determined (block 214), and receiving/monitoring of the signal(s) (block 216) can resume, such as during operation of a machine including a monitored tip shroud. The remainder of this example of method 200 is substantially identical to that shown in FIG. 5, with the receiving/monitoring of block 216 being substituted for that of block 210. In embodiments, the determining of the baseline sensed pattern (block 212) can include storing a first series of values of the signal(s) for a revolution of the tip shroud (block 213), though other manners of determining the baseline sensed pattern can be used as desired and/or appropriate. A loop may be performed after an initial baseline pattern is determined (block 212) and, in embodiments, after determining the defined amount(s) of allowable change or deviation (block 214), the loop including receiving/monitoring the signal(s) (block 216), checking for a change in a signal value (block 220), and returning to receiving/monitoring the signal(s) (block 216) if there is no change in a signal value or if a change is not greater than the defined amount (block 222) and repeating the loop. As noted above, additional embodiments can determine whether the change in a value of a signal is greater than or equal to the defined amount in block 222.

[0022] A further example of a tip shroud monitoring method 200 according to embodiments is shown in FIG. 7. This example builds on the example of FIG. 6 and adds a determination of an operation sensed pattern (block 217) for each tip shroud and/or signal. For example, a second series of values of each signal for another, sub-

sequent revolution of the tip shroud can be stored (block 218), though any suitable manner of determining the operation sensed pattern can be used as may be desired and/or appropriate. In addition, the check for a change in value of the signal(s) can include determining whether the operation sensed pattern deviates from the baseline sensed pattern (block 220). If no change has occurred, or if no change greater than the defined amount(s) has occurred (block 222), then receiving and/or monitoring of the signal(s) can resume. In embodiments, before resuming receiving/monitoring of the signal(s), each baseline sensed pattern can be replaced with a respective operation sensed pattern (block 224). In other words, a current operation sensed pattern can become a new baseline sensed pattern, and another operation sensed pattern can be determined (block 217). A loop may therefore be performed after an initial baseline pattern is determined (block 212), the loop including receiving/monitoring the signal(s) (block 216), determining an operation sensed pattern (block 217), checking for a deviation of the operation sensed pattern from the baseline sensed pattern (block 220), replacing the baseline sensed pattern with the operation sensed pattern (block 224) if there is no deviation or if a deviation is not greater than the defined amount (block 222), then returning to receiving/monitoring the signal(s) (block 216) and repeating the loop. As noted above, additional embodiments can determine whether the change in a value of a signal, or deviation from the baseline sensed pattern by the operation sensed pattern, is greater than or equal to the defined amount in block 222.

[0023] A technical effect of the systems and methods described herein includes providing an indication of possible damage to a tip shroud of a rotor, such as a turbine rotor, a compressor rotor, or other rotor. An additional technical effect can include shutting down the machine to inspect the flagged tip shroud for damage. A further technical effect can include avoiding damage resulting from a failure of a tip shroud by detection of possible tip shroud damage before more significant damage can occur. Another technical effect can include extending operative life of a machine by enabling replacement and/or repair of damaged tip shroud components before more severe damage can occur.

[0024] Turning to FIG. 8, an illustrative environment 400 for a tip shroud monitoring computer program product is schematically illustrated according to an embodiment of the invention. To this extent, environment 400 includes a computer system 410, such as control system or controller 120 and/or other computing device that can be part of a machine control system that can perform a process described herein in order to execute a tip shroud monitoring method according to embodiments. In particular, computer system 410 is shown including a tip shroud monitoring program 420, which makes computer system 410 operable to manage data in a tip shroud monitoring control system or controller by performing a process described herein, such as an embodiment of the tip shroud

monitoring method 200 discussed above.

[0025] Computer system 410 is shown including a processing component or unit (PU) 412 (e.g., one or more processors), an input/output (I/O) component 414 (e.g., one or more I/O interfaces and/or devices), a storage component 416 (e.g., a storage hierarchy), and a communications pathway 417. In general, processing component 412 executes program code, such as tip shroud monitoring program 420, which is at least partially fixed in storage component 416, which can include one or more non-transitory computer readable storage medium or device. While executing program code, processing component 412 can process data, which can result in reading and/or writing transformed data from/to storage component 416 and/or I/O component 414 for further processing. Pathway 417 provides a communications link between each of the components in computer system 410. I/O component 414 can comprise one or more human I/O devices, which enable a human user to interact with computer system 410 and/or one or more communications devices to enable a system user to communicate with computer system 410 using any type of communications link. In addition, I/O component 414 can include one or more sensors, such as voltage, frequency, and/or current sensors as discussed above. In embodiments, a communications arrangement 430, such as networking hardware/software, enables computing device 410 to communicate with other devices in and outside of a machine, such as a turbomachine, and/or component and/or control system in which it is installed. To this extent, tip shroud monitoring program 420 can manage a set of interfaces (e.g., graphical user interface(s), application program interface, and/or the like) that enable human and/or system users to interact with tip shroud monitoring program 420. Further, tip shroud monitoring program 420 can manage (e.g., store, retrieve, create, manipulate, organize, present, etc.) data, such as tip shroud monitoring data 418, using any solution. In embodiments, data can be received from one or more sensors, such as voltage, frequency, and/or current sensors as discussed above.

[0026] Computer system 410 can comprise one or more general purpose computing articles of manufacture (e.g., computing devices) capable of executing program code, such as tip shroud monitoring program 420, installed thereon. As used herein, it is understood that "program code" means any collection of instructions, in any language, code or notation, that cause a computing device having an information processing capability to perform a particular action either directly or after any combination of the following: (a) conversion to another language, code or notation; (b) reproduction in a different material form; and/or (c) decompression. Additionally, computer code can include object code, source code, and/or executable code, and can form part of a computer program product when on at least one computer readable medium. It is understood that the term "computer readable medium" can comprise one or more of any type of tangible, non-transitory medium of expression, now

known or later developed, from which a copy of the program code can be perceived, reproduced, and/or otherwise communicated by a computing device. For example, the computer readable medium can comprise: one or more portable storage articles of manufacture, including storage devices; one or more memory/storage components of a computing device; paper; and/or the like. Examples of memory/storage components and/or storage devices include magnetic media (floppy diskettes, hard disc drives, tape, etc.), optical media (compact discs, digital versatile/video discs, magneto-optical discs, etc.), random access memory (RAM), read only memory (ROM), flash ROM, erasable programmable read only memory (EPROM), or any other tangible, non-transitory computer readable storage medium now known and/or later developed and/or discovered on which the computer program code is stored and with which the computer program code can be loaded into and executed by a computer. When the computer executes the computer program code, it becomes an apparatus for practicing the invention, and on a general purpose microprocessor, specific logic circuits are created by configuration of the microprocessor with computer code segments.

[0027] The computer program code can be written in computer instructions executable by the controller or computing device, such as in the form of software encoded in any programming language. Examples of suitable computer instruction and/or programming languages include, but are not limited to, assembly language, Verilog, Verilog HDL (Verilog Hardware Description Language), Very High Speed IC Hardware Description Language (VHSIC HDL or VHDL), FORTRAN (Formula Translation), C, C++, C#, Java, ALGOL (Algorithmic Language), BASIC (Beginner All-Purpose Symbolic Instruction Code), APL (A Programming Language), ActiveX, Python, Perl, php, Tcl (Tool Command Language), HTML (HyperText Markup Language), XML (extensible Markup Language), and any combination or derivative of one or more of these and/or others now known and/or later developed and/or discovered. To this extent, tip shroud monitoring program 420 can be embodied as any combination of system software and/or application software.

[0028] Further, tip shroud monitoring program 420 can be implemented using a set of modules 422. In this case, a module 422 can enable computer system 410 to perform a set of tasks used by tip shroud monitoring program 420, and can be separately developed and/or implemented apart from other portions of tip shroud monitoring program 420. As used herein, the term "component" means any configuration of hardware, with or without software, which implements the functionality described in conjunction therewith using any solution, while the term "module" means program code that enables a computer system 410 to implement the actions described in conjunction therewith using any solution. When fixed in a storage component 416 of a computer system 410 that includes a processing component 412, a module is a substantial portion of a component that implements the actions. Re-

ardless, it is understood that two or more components, modules, and/or systems can share some/all of their respective hardware and/or software. Further, it is understood that some of the functionality discussed herein may not be implemented or additional functionality may be included as part of computer system 410.

[0029] When computer system 410 comprises multiple computing devices, each computing device can have only a portion of tip shroud monitoring program 420 fixed thereon (e.g., one or more modules 422). However, it is understood that computer system 410 and tip shroud monitoring program 420 are only representative of various possible equivalent computer systems that can perform a process described herein. To this extent, in other embodiments, the functionality provided by computer system 410 and tip shroud monitoring program 420 can be at least partially implemented by one or more computing devices that include any combination of general and/or specific purpose hardware with or without program code. In each embodiment, the hardware and program code, if included, can be created using standard engineering and programming techniques, respectively.

[0030] Regardless, when computer system 410 includes multiple computing devices, the computing devices can communicate over any type of communications link. Further, while performing a process described herein, computer system 410 can communicate with one or more other computer systems using any type of communications link. In either case, the communications link can comprise any combination of various types of wired and/or wireless links; comprise any combination of one or more types of networks; and/or utilize any combination of various types of transmission techniques and protocols now known and/or later developed and/or discovered.

[0031] As discussed herein, tip shroud monitoring program 420 enables computer system 410 to implement a tip shroud monitoring product and/or method, such as that shown schematically in FIGS. 5-7. Computer system 410 can obtain tip shroud monitoring data 418 using any solution. For example, computer system 410 can generate and/or be used to generate tip shroud monitoring data 418, retrieve tip shroud monitoring data 418 from one or more data stores, and/or receive tip shroud monitoring data 418 from another system or device, such as one or more sensors, in or outside of a machine, such as a turbomachine, a control system, and/or the like.

[0032] In another embodiment, the invention provides a method of providing a copy of program code, such as tip shroud monitoring program 420 (FIG. 8), which implements some or all of a process described herein, such as that shown schematically in and described with reference to FIGS. 5-7. In this case, a computer system can process a copy of program code that implements some or all of a process described herein to generate and transmit, for reception at a second, distinct location, a set of data signals that has one or more of its characteristics set and/or changed in such a manner as to encode a copy of the program code in the set of data signals. Sim-

ilarly, an embodiment of the invention provides a method of acquiring a copy of program code that implements some or all of a process described herein, which includes a computer system receiving the set of data signals described herein, and translating the set of data signals into a copy of the computer program fixed in at least one tangible, non-transitory computer readable medium. In either case, the set of data signals can be transmitted/received using any type of communications link.

[0033] In still another embodiment, the invention provides a method of generating a system for implementing a tip shroud monitoring product and/or method. In this case, a computer system, such as computer system 410 (FIG. 8), can be obtained (e.g., created, maintained, made available, etc.), and one or more components for performing a process described herein can be obtained (e.g., created, purchased, used, modified, etc.) and deployed to the computer system. To this extent, the deployment can comprise one or more of: (1) installing program code on a computing device; (2) adding one or more computing and/or I/O devices to the computer system; (3) incorporating and/or modifying the computer system to enable it to perform a process described herein; and/or the like.

[0034] 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

1. A monitoring system (100) for a tip shroud (26) of a rotor (20), the system comprising:

a sensor (110) responsive to the tip shroud (26); and
a control system (120) configured to:

receive a signal from the sensor (110);
monitor the signal from the sensor (110);
compare a value of a characteristic of the signal to a reference value of the characteristic; and
indicate possible tip shroud damage responsive to an amount of change in the value of the characteristic of the signal exceeding a defined amount of allowable change.

2. The monitoring system of claim 1, wherein the reference value includes a previously received value of the characteristic.
3. The monitoring system of claim 1 or 2, wherein the control system (120) is further configured to determine a baseline sensed pattern (130) using the signal, the reference value including the baseline sensed pattern (130) and wherein, comparing the value of the characteristic of the signal to the reference value includes comparing the value to the baseline sensed pattern (120), and the control system is further configured to determine the amount of change between the value and the baseline sensed pattern (130).
4. The monitoring system of claim 3, wherein the control system (120) is further configured to perform the following:
 - determine, as part of monitoring the signal from the sensor (110), an operation sensed pattern using the signal from the sensor;
 - determine, as part of comparing the signal to the reference value, an amount of change between corresponding portions of the operation sensed pattern and the baseline sensed pattern (120);
 - and
 - indicate possible tip shroud damage responsive to an amount of change exceeding the defined amount.
5. The monitoring system of claim 4, wherein the baseline sensed pattern (130) is an immediately previous operation sensed pattern.
6. The monitoring system of claim 4 or 5, wherein, to determine the baseline sensed pattern (130), the control system (120) is further configured store a first series of values of the characteristic of the respective signal during a revolution of the tip shroud (26), and to determine the operation sensed pattern, the control system (120) is further configured to store a second series of values of the characteristic of the signal during a subsequent revolution of the tip shroud (26), each of the second series of values corresponding to a respective one of the first series of values.
7. A method (200) for monitoring a tip shroud (26) of a rotor (20), the method comprising:
 - receiving (210) a signal indicative of a presence of the tip shroud (26);
 - monitoring (210) a value of a characteristic of the signal;
 - determining (220) an amount of change in the value of a characteristic of the signal;
 - comparing (222) the amount of change to a defined amount of allowable change; and
 - indicating possible damage to the tip shroud (26) responsive to the amount of change exceeding a defined amount of allowable change.
8. The method of claim 7, wherein the monitoring of the value includes determining (212) a baseline sensed pattern (130) of the value for a revolution of an undamaged tip shroud (26), and the determining (220) of an amount of change includes comparing the monitored value to a corresponding portion of the baseline sensed pattern (130).
9. The method of claim 8, wherein:
 - the monitoring of the value includes determining (217) an operation sensed pattern of the value of the characteristic of the signal during a subsequent revolution of the tip shroud (26); and
 - the determining (220) of an amount of change further includes determining a change between corresponding portions of the baseline sensed pattern (130) and the operation sensed pattern, wherein the indicating of possible damage is responsive to the amount of change between corresponding values exceeding the defined amount.
10. The method of claim 9, further comprising replacing the baseline sensed pattern (130) with the operation sensed pattern, repeating the determining (217) an operation sensed pattern for another revolution of the tip shroud (26), repeating the determining an amount of change between corresponding portions of the baseline sensed pattern (130) and the operation sensed pattern, and repeating the indicating possible tip shroud damage responsive to the amount of change between corresponding portions exceeding the defined amount.
11. The method of claim 9 or 10, wherein determining a baseline sensed pattern (130) includes storing (213) a first series of values of the monitored characteristic for the revolution of the tip shroud (26), the determining of the operation sensed pattern includes storing (218) a second series of values of the monitored characteristic or the subsequent revolution of the tip shroud (26), each of the second series of values corresponding to a respective one of the first series of values.
12. The method of any of claims 7 to 11, further comprising determining (220) the defined amount using at least one of manufacturing tolerances of the tip shroud (26), a characteristic of an environment in which the tip shroud (26) operates, or deflection of at least one component of the tip shroud.

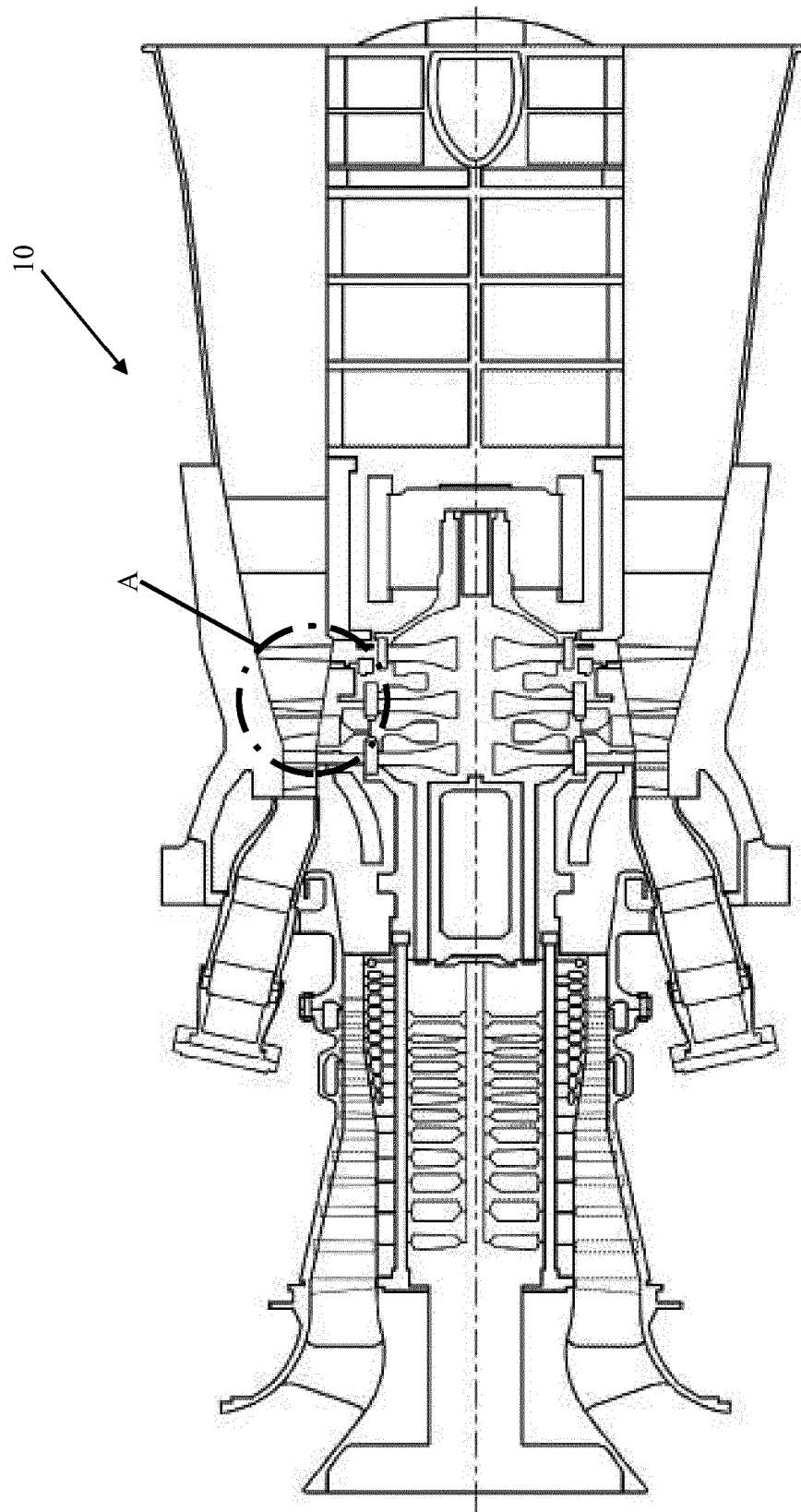


FIG. 1

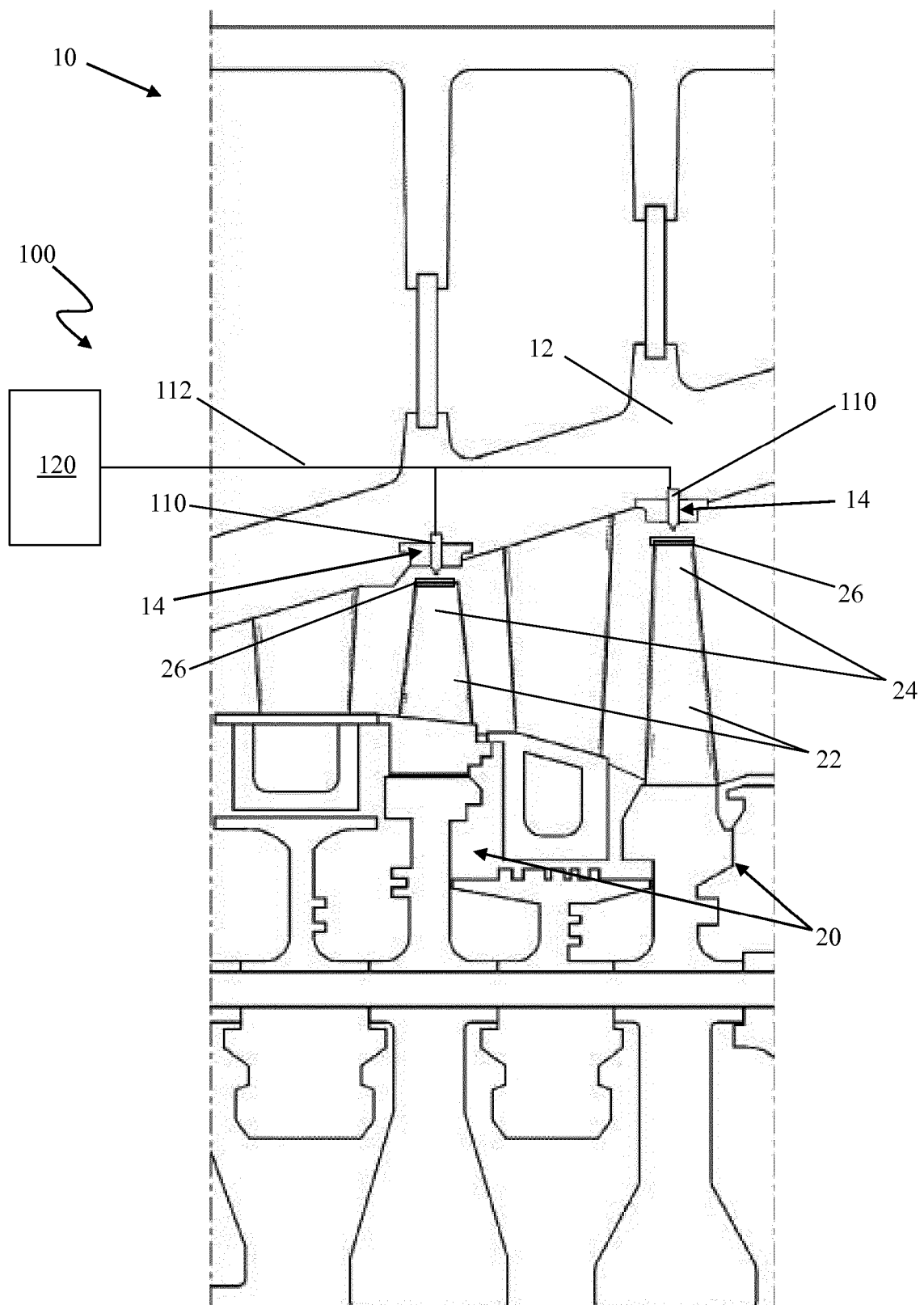


FIG. 2

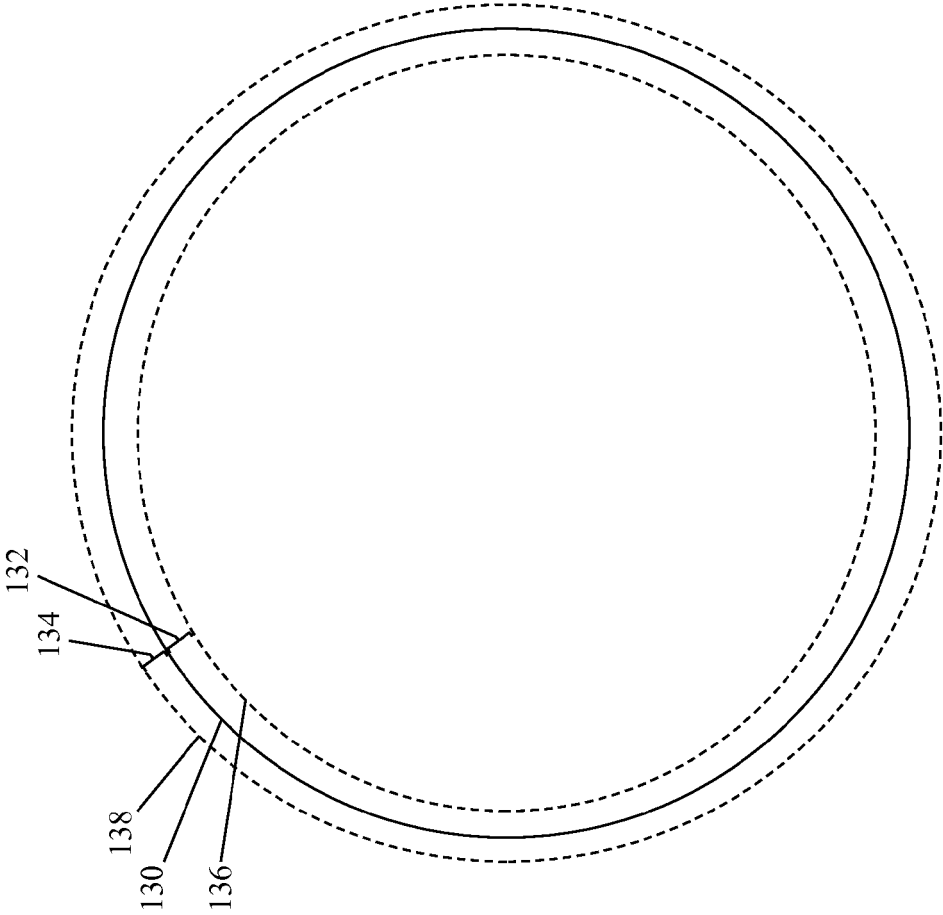


FIG. 3

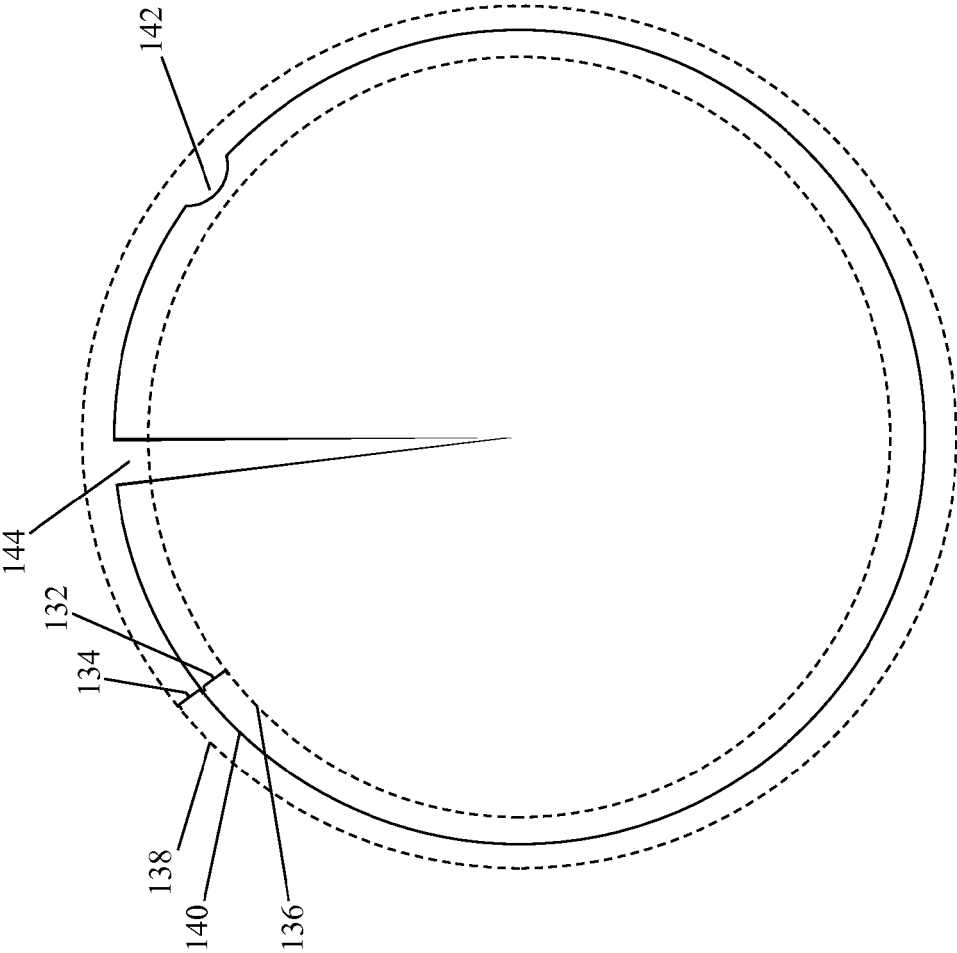


FIG. 4

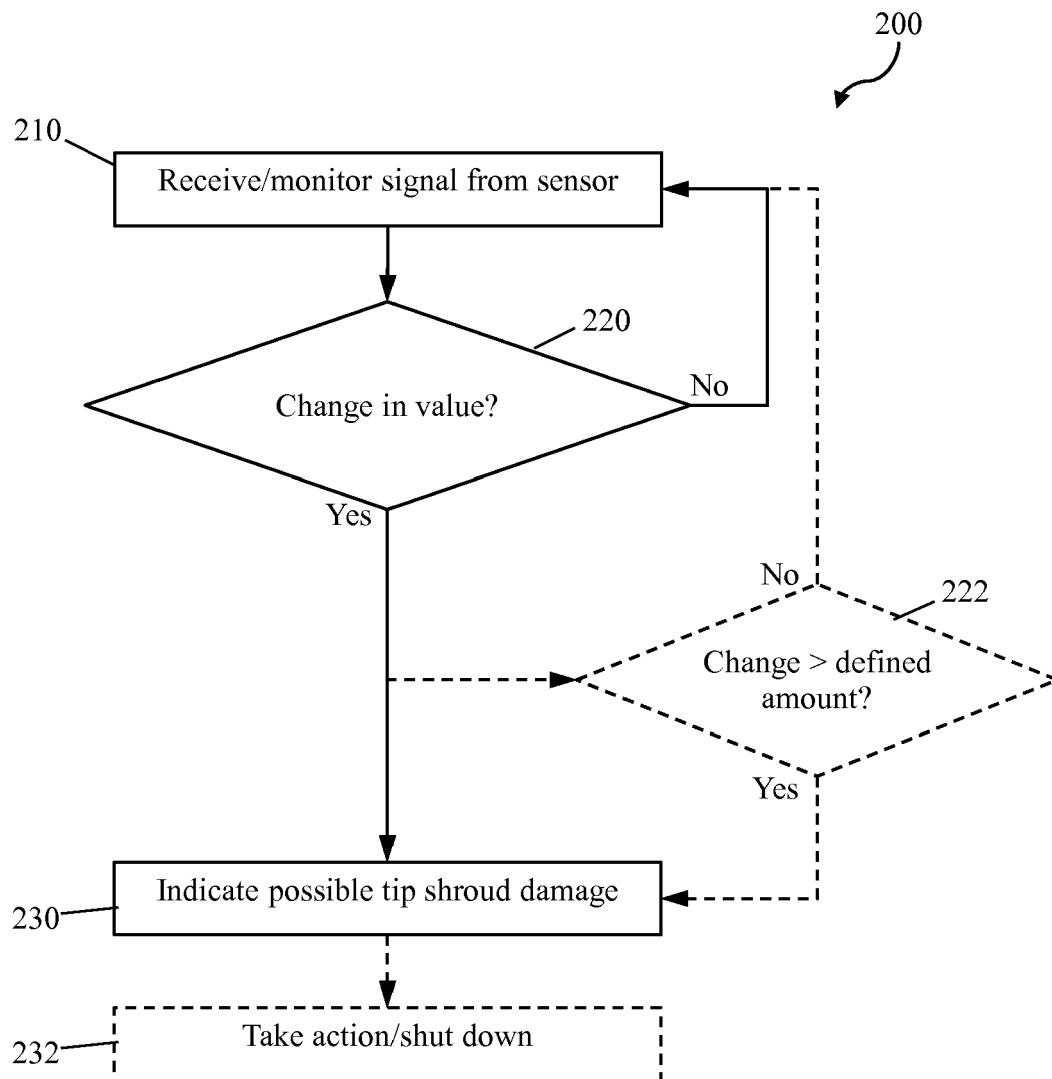


FIG. 5

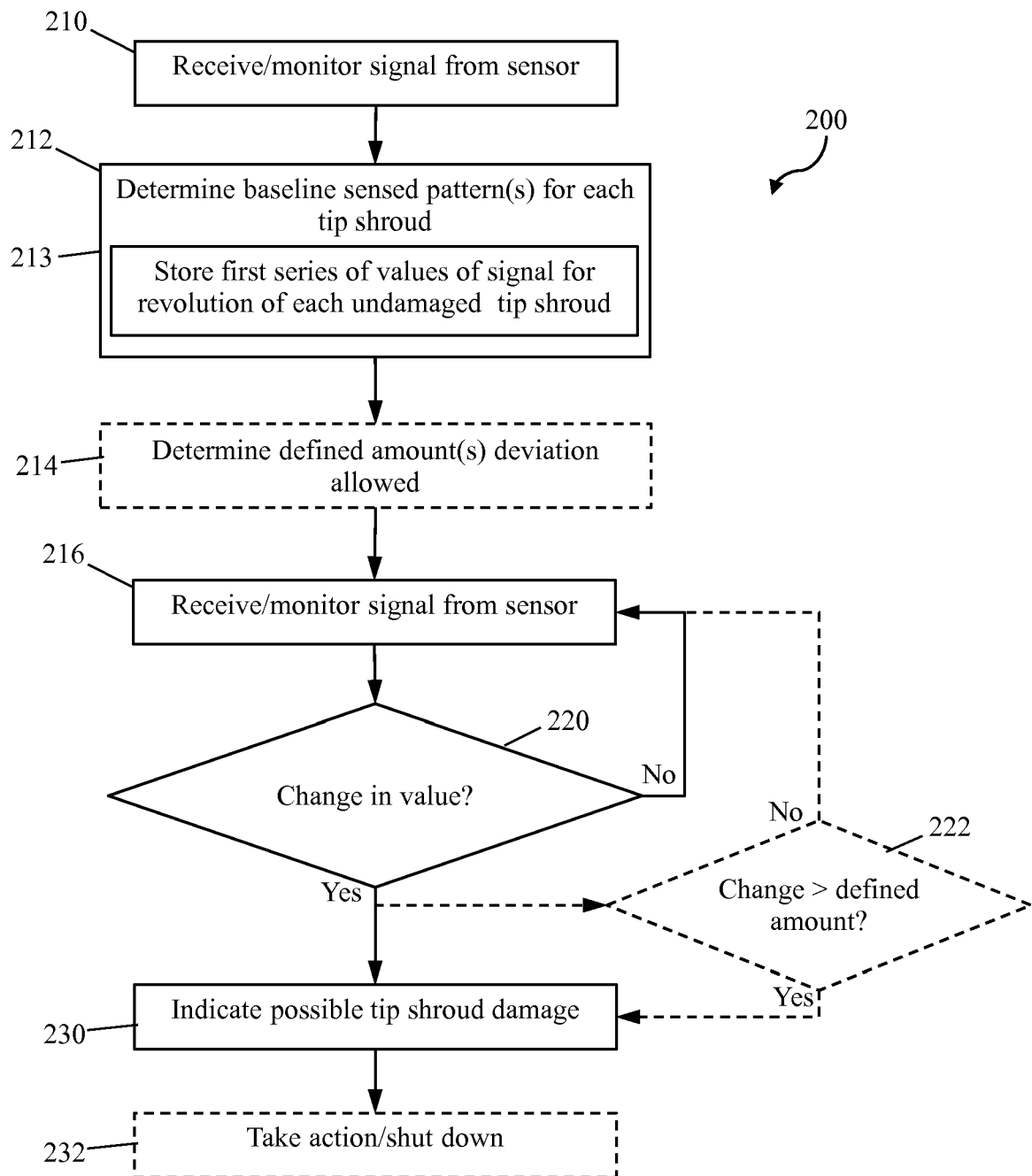


FIG. 6

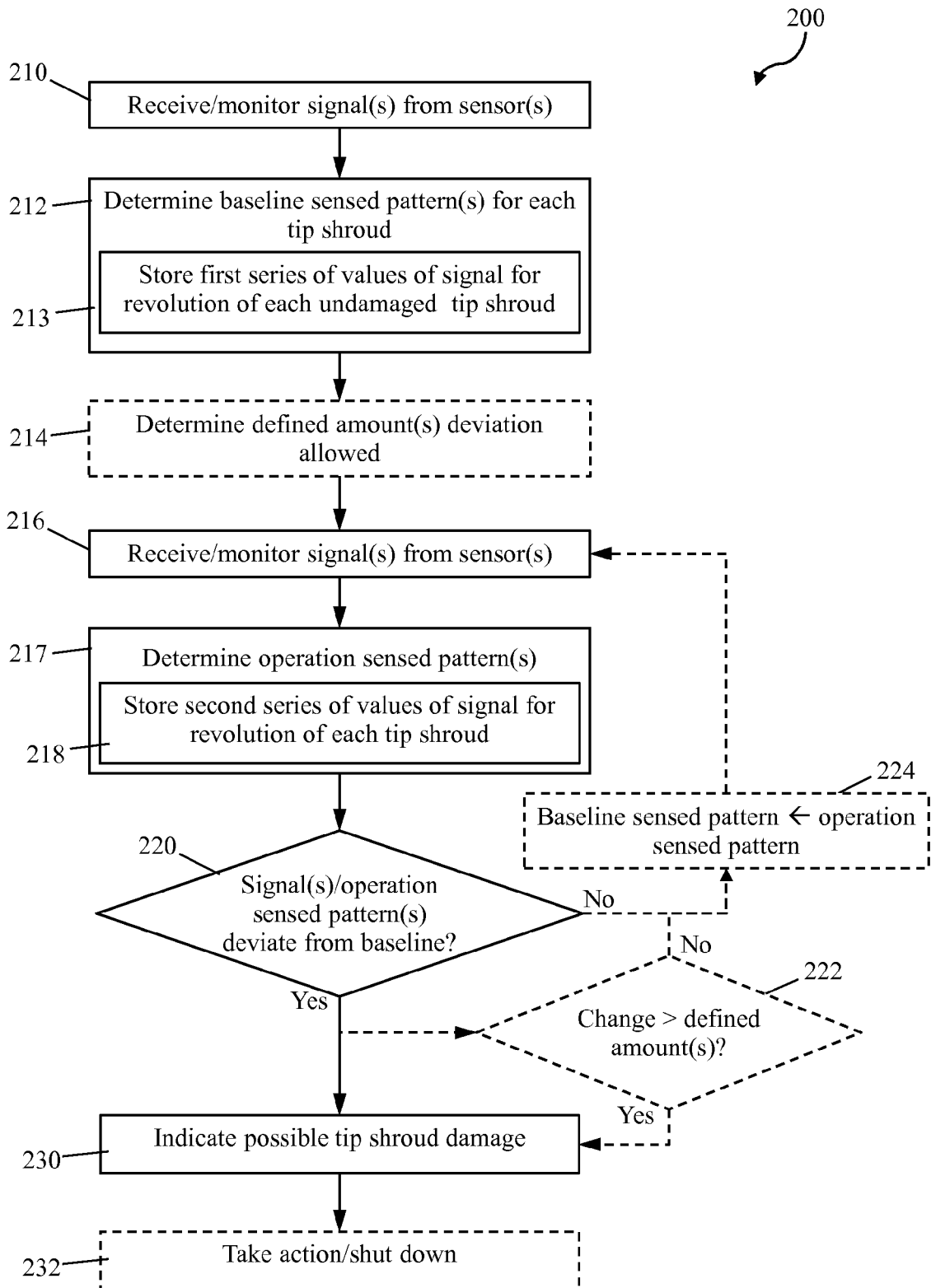


FIG. 7

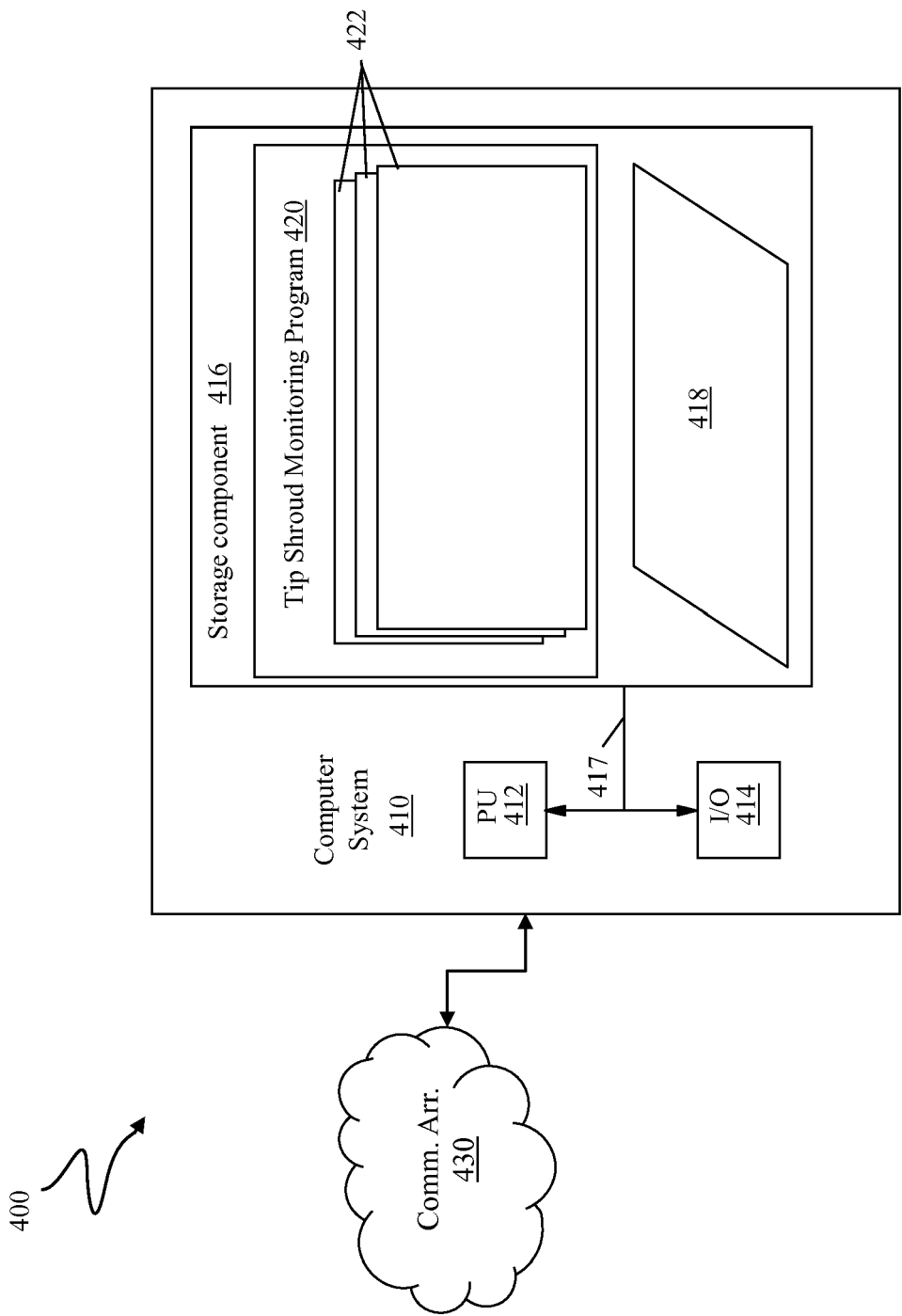


FIG. 8