the blowout preventer. The pressurizing system can be a closed system that includes a pump for pressurizing the blowout preventer, the blowout preventer, and one or more lines coupling the pump to the blowout preventer. The computing device can also receive real-time pressure measurements from a pressure sensor within the pressurizing system. The pressure measurements can indicate pressures in the pressurizing system. The computing device can generate the model based on the predetermined values and the pressure measurements. The computing device can use the model to predict pressures in the pressurizing system over a future period of time. The computing device can analyze aspects of the predicted pressures in the pressurizing system over the future period of time to determine if the blowout preventer is functioning properly.

[0008] For example, the computing device can determine if a rate, which can be referred to as the decay rate, at which pressure in the pressurizing system decays during the future period of time is within acceptable limits. An example of the acceptable limits can be between three pounds per square inch (psi) or 20,684.27 Pascals (Pa) per minute and five psi or 34,473.79 Pa per minute. If so, the computing device can determine that the blowout preventer is functioning properly. Additionally or alternatively, the computing device can determine if the decay rate will remain within the acceptable limits for an acceptable time period (e.g., at least five minutes). If so, the computing device can determine that the blowout preventer is functioning properly. Additionally or alternatively, the computing device can determine a pressure level in the pressurizing system when the pressure in the blowout preventer is substantially constant or stable (e.g., no longer decaying). If the pressure level is within an acceptable range of pressures, such as between 1,000 psi or 6,894,757 Pa and 20,000 psi or 137,895,146 Pa, the computing device can determine that the blowout preventer is functioning properly. The computing device can use any combination of the above criteria to determine of the blowout preventer is functioning properly (or improperly).

[0009] Using the model to determine if the blowout preventer is functioning properly can be substantially faster and less expensive than testing the blowout preventer using other methods. For example, if the well operator is only relying on real-time sensor data from the pressure sensor to determine how the pressure in the pressurizing system changes over time, it may take 45 minutes or longer to receive enough pressure measurements from the pressure sensor to make an accurate

[0013] The well system 100 can include a riser 118. A riser 118 can include a tubular that couples the blowout preventer 112 to the drilling rig 102 for allowing fluid, such as production fluid, to flow from the wellbore 106 to the drilling rig 102.

[0014] The well system 100 can include a pump 120. The pump 120 can pump or otherwise communicate fluid (e.g., an oil-based mud or a synthetic-based mud) through one or more pipes or lines 122a-b to the blowout preventer 112 to test or otherwise pressurize the blowout preventer 112. The lines 122a-b can include a choke line and a kill line.

[0015] The pump 120, the line 122a, the line 122b, the blowout preventer 112, or any combination of these can form a pressurizing system for pressurizing the blowout preventer 112. In some examples, the pressurizing system can be a closed system. A sensor 126, such as a pressure sensor, can be coupled to the pressurizing system for detecting pressure in the pressurizing system (e.g., pressure in the blowout preventer 112). For example, the sensor 126 can be coupled to line 122a, line 122b, pump 120, or blowout preventer 112 for detecting the pressure in the pressurizing system during a test. The sensor 126 can transmit sensor data associated with the pressure to the computing device 124 via a wired interface 128 or a wireless interface 130. The computing device 124 can receive the sensor data and use the sensor data to determine if the blowout preventer 112 is functioning properly.

[0016] For example, the computing device 124 can cause the pump 120 to pressurize the pressurizing system to a testing pressure level, such as 7,000 psi or 48,263,299 Pa. As shown in FIG. 2, the increasing line between times t_0 and t_1 can indicate that the pump 120 is pressurizing the pressurizing system to the testing pressure level (P_{test}). The computing device 124 can analyze sensor data from the sensor 126 to determine if the pressure in the pressurizing system has reached the testing pressure level. If so, the computing device 124 can cause the pump 120 to stop pressurizing the pressurizing system. Thereafter, due to thermal cooling and other environmental factors, the pressure in the pressurizing system can decay over time (e.g., as shown between times t_1 and t_3 of FIG. 2). The computing device 124 can analyze sensor data taken at intervals between times t_1 and t_3 and determine, based on the sensor data, if the blowout preventer 112 is functioning properly. For example, if the blowout preventer 112 is functioning properly, the pressure in the pressurizing system can decay at an acceptable rate, such as three to five psi or

20,684.27 Pa to 34,473.79 Pa /minute over a five minute time period, and the pressure in the pressurizing system can eventually stabilize to a pressure level (P_{stable}) that is greater than or equal to a target pressure level, such as 6,000 psi or 41,368,542 Pa. If the blowout preventer 112 is not functioning properly (e.g., if the blowout preventer 112 is leaking), the pressure level in the pressurizing system may decay too quickly, may not stabilize, or may stabilize at a pressure level below the target pressure level. The computing device 124 can determine a rate of decay of the pressure in the pressurizing system, a pressure level at which the pressure in the pressurizing system stabilizes, or both of these, to determine if the blowout preventer 112 is operating properly or malfunctioning.

[0017] But it can take a significant amount of time to perform the above-described test. For example, the time period between t_0 and t_3 can be 45 minutes or longer. And this test may need to be performed on every section 116 of the blowout preventer 112, leading to multiple hours of testing in total, which can be expensive and burdensome for well operators. Further, some laws or regulations require the blowout preventer 112 to be tested weekly, biweekly, or at other short intervals, thereby requiring well operators to perform this test frequently to great expense. Some examples of the present disclosure can overcome these and other issues using a model executing on the computing device 124.

[0018] For example, the computing device 124 can receive sensor data from the sensor 126 for a limited time period, such the time period between time t_0 and t_2 shown in FIG. 2. The computing device 124 can then use the sensor data to generate a model of the pressure in the pressurizing system over time, as shown by the dashed line 204. The computing device 124 can use the model to predict the rate of decay of the pressure in the pressurizing system, a pressure level at which the pressure in the pressurizing system will stabilize, a time when the pressure in the pressurizing system will stabilize, or any combination of these. For example, the computing device 124 can use the model to predict the pressure level in the pressurizing system at time t_3, and whether the pressure in the pressurizing system will stabilize at time t_3. The computing device 124 can then use the predicted rate of decay, pressure level, time, or any combination of these to determine if the blowout preventer 112 is operating properly. This process can be performed faster, and can require less sensor data, than other methods for testing the blowout preventer 112.

[0019] One example of the model can include the equation:

[0029] In block 402, the computing device 124 causes the pump 120 to pressurize a pressurizing system. The pressurizing system can include at least one of the pump 120, the line 122a, the line 122b, or the blowout preventer 112. For example, the computing device 124 can transmit power or a command to the pump 120, or manipulate a power source, to cause the pump 120 to pump fluid through the pressurizing system to pressurize the pressurizing system. In some examples, the fluid can be an oil-based mud or a synthetic-based mud.

[0030] In block 404, the computing device 124 determines if the pressure level in the pressurizing system is greater than or equal to a testing pressure-level, such as 7,000 psi or 48,263,299 Pa. For example, the computing device 124 can receive sensor signals from the sensor 126, where the sensor signals indicate a pressure level in the pressurizing system. The computing device 124 can analyze the sensor signals to determine if the pressure level in the pressurizing system is greater than or equal to the testing pressure-level. If the computing device 124 determines that the pressure level in the pressurizing system is less than the testing pressure-level, the computing device 124 can continue to cause the pump 120 to pressurize the pressurizing system. Otherwise, the process can continue to block 406.

[0031] In block 406, the computing device 124 causes the pump 120 to stop pressurizing the pressurizing system. For example, the computing device 124 can stop transmitting power to the pump 120, transmit a command to the pump 120, or manipulate a power source to cause the pump 120 to stop pressurizing the pressurizing system.

[0032] In block 408, the computing device 124 receives one or more predetermined values, such as values for m_1 and m_2 of a model. The model can be at least partially based on a thermal-cooling characteristic of the pressurizing system or a wellbore 106 associated with the blowout preventer 112. In some examples, the computing device 124 can receive the predetermined values from a remote computing device (e.g., that is offsite). In other examples, the computing device 124 can receive the predetermined values from memory. In such examples, the computing device 124 may have previously determined or received the predetermined values and stored the values in memory.

[0033] For example, the computing device 124 can determine the predetermined values based on information from a previous blowout-preventer test. The previous blowout-preventer test can include pressurizing the pressurizing

[0037] In some examples, blocks 410-414 can be iterated for multiple sensor measurements over a time period. For example, the computing device 124 can receive multiple sensor measurements indicating multiple pressures in the pressurizing system over a time period. If the blowout preventer 112 is functioning properly, the values for the model (e.g., A_0, A_1, A_2, m_1, m_2, or any combination of these) can become substantially stable after several iterations. The values for the model can be considered substantially stable if the values remain substantially constant (e.g., within a tolerance range of 5%) over multiple iterations. Additionally or alternatively, if the blowout preventer 112 is functioning properly, the accuracy of the model can be high (e.g., above a predetermined quality-threshold). In some examples, the computing device 124 can determine if the some or all of the values for the model are substantially stable and the accuracy of the model is high, as shown in block 416.. If so, the process continues to block 418. Otherwise, the process can return to block 410.

[0038] In block 418, the computing device 124 uses the model to predict pressures in the pressurizing system over a future period of time. For example, the computing device 124 can plug different future times (t) into the above-described equation to determine pressures in the pressurizing system at those future times.

[0039] In block 420, the computing device 124 determines a rate of decay of the pressure in the pressurizing system during the future period of time. For example, the computing device 124 can use the model to predict changes in the pressure in the pressurizing system over the future period of time. The computing device 124 can then determine a rate at which the pressure in the pressurizing system will change over the future period of time and use the rate of change as the rate of decay.

[0040] In block 422, the computing device 124 determines a future time at which the rate of decay will be within an acceptable range. In some examples, the acceptable range can be between three psi or 20,684.27 Pa /minute and six psi‒ or 41,368.54 Pa /minute. The computing device 124 can also determine if the rate of decay will remain in the acceptable range for a predetermined period of time (e.g., at least three minutes).

[0041] In block 424, the computing device 124 determines if the rate of decay is (or will be) within an acceptable range. In some examples, if the computing device 124 determines that the rate of decay will never (during the future period of time) be

within the acceptable range, the computing device 124 can determine that the blowout preventer 112 failed the test. In some examples, if the computing device 124 determines that the rate of decay is (or will be) within an acceptable range, the computing device 124 can determine that the blowout preventer 112 passed the test, or the process can continue to block 426.

[0042] In block 426, the computing device 124 determines a pressure level at which the pressure in the pressurizing system will substantially stabilize. The pressure level can be considered substantially stable if the pressure level remains substantially constant (e.g., within a tolerance range of 5%) over a time period. For example, the computing device 124 can use the model to predict pressures in the pressurizing system over a future period of time. The computing device 124 can analyze the predicted pressures in the pressurizing system to determine if the pressure in the pressurizing system will ever (during the future period of time) become substantially stable. If so, the computing device 124 can determine the pressure level at which the pressure in the pressurizing system becomes substantially stable.

[0043] In block 428, the computing device 124 determines if the pressure level (at which the pressure in the pressurizing system is substantially stable) is within an acceptable range of pressures. An example of the acceptable range can be between 5,900 psi or 40,679,068 Pa and 6,100 psi or 42,058,019 Pa. If the computing device 124 determines that the pressure level is within the acceptable range of pressures, the computing device 124 can determine that the blowout preventer 112 passed the test. Otherwise, the computing device 124 can determine that the blowout preventer 112 failed the test.

[0044] In some aspects, systems, computer-readable mediums, and methods for analyzing a blowout preventer are provided according to one or more of the following examples:

[0045] Example #1: A system can include a pressure sensor that is positionable in a pressurization subsystem for pressurizing a blowout preventer. The pressure sensor can be for detecting pressure in the pressurization subsystem. The system can include a computing device communicatively coupled to the pressure sensor. The computing device can include a processing device and a memory device on which instructions are stored. The instructions can cause the processing device to receive multiple predetermined values associated with pressure changes in

the pressurization subsystem over time. The instructions can cause the processing device to receive, from the pressure sensor, multiple pressure measurements indicating multiple pressures in the pressurization subsystem over a time period. The instructions can cause the processing device to generate, based on the multiple predetermined values and the multiple pressure measurements, a model representing a relationship between pressure in the pressurization subsystem and time. The instructions can cause the processing device to predict, using the model, pressures in the pressurization subsystem over a future period of time that is subsequent to the time period.

[0046] Example #2: The system of Example #1 may feature the memory device further including instructions for causing the processing device to determine, by analyzing the predicted pressures in the pressurization subsystem over the future period of time, a rate of decay of the pressure in the pressurization subsystem during the future period of time. The instructions may also cause the processing device to determine that the rate of decay is within a range of acceptable decay rates.

[0047] Example #3: The system of Example #2 may feature the range of acceptable decay rates being between three pounds per square inch (psi) or 20,684.27 Pa per minute and five psi or 34,473.79 Pa per minute.

[0048] Example #4: The system of any of Examples #2-3 may feature the memory device further including instructions for causing the processing device to determine, by analyzing the predicted pressures in the pressurization subsystem over the future period of time, that the rate of decay will be within the range of acceptable decay rates for an acceptable period of time that is at least five minutes long.

[0049] Example #5: The system of any of Examples #1-4 may feature the memory device further including instructions for causing the processing device to determine, by analyzing the predicted pressures in the pressurization subsystem over the future period of time, a pressure level at which the pressure in the pressurization subsystem is substantially stable. The instructions may also cause the processing device to determine that the pressure level is within an acceptable range of pressures.

[0050] Example #6: The system of Example #5 may feature the acceptable range of pressures being between 1,000 psi or 6,894,757 Pa and 20,000 psi or 137,895,146 Pa.

[0051] Example #7: The system of any of Examples #1-6 may feature the model being based on a thermal-cooling characteristic of the pressurization subsystem.

[0052] Example #8: A non-transitory computer-readable medium can store instructions executable by a processing device. The instructions can cause the processing device to receive multiple predetermined values associated with pressure changes in a pressurization subsystem over time. The pressurization subsystem can be for pressurizing a blowout preventer in a well system. The instructions can cause the processing device to receive, from a pressure sensor, multiple pressure measurements indicating multiple pressures in the pressurization subsystem over a time period. The instructions can cause the processing device to generate, based on the multiple predetermined values and the multiple pressure measurements, a model representing a relationship between pressure in the pressurization subsystem and time. The instructions can cause the processing device to predict, using the model, pressures in the pressurization subsystem over a future period of time that is subsequent to the time period.

[0053] Example #9: The non-transitory computer-readable medium of Example #8 may feature instructions for causing the processing device to determine, by analyzing the predicted pressures in the pressurization subsystem over the future period of time, that a rate of decay of the pressure in the pressurization subsystem will remain within a range of acceptable decay rates for an acceptable period of time.

[0054] Example #10: The non-transitory computer-readable medium of Example #9 may feature the range of acceptable decay rates being between three psi or 20,684.27 Pa per minute and five psi or 34,473.79 Pa, and the acceptable period of time being at least five minutes.

[0055] Example #11: The non-transitory computer-readable medium of any of Examples #8-10 may feature instructions for causing the processing device to, prior to the time period, cause a pump of the pressurization subsystem to communicate an oil-based mud or a synthetic-based mud through the pressurization subsystem to pressurize the pressurization subsystem.

[0056] Example #12: The non-transitory computer-readable medium of any of Examples #8-11 may feature instructions for causing the processing device to determine, by analyzing the predicted pressures in the pressurization subsystem over the future period of time, a pressure level at which the pressure in the

pressurization subsystem is substantially stable. The instructions may also cause the processing device to determine that the pressure level is within an acceptable range of pressures.

[0057] Example #13: The non-transitory computer-readable medium of Example #12 may feature the acceptable range of pressures being between 1000 psi or 6,894,757 Pa and 20,000 psi or 137,895,146 Pa.

[0058] Example #14: The non-transitory computer-readable medium of any of Examples #8-13 may feature the model being based on a thermal-cooling characteristic of the blowout preventer.

[0059] Example #15: A method can include receiving, by a computing device, multiple predetermined values associated with pressure changes in a pressurization subsystem over time. The pressurization subsystem can be for pressurizing a blowout preventer in a well system. The method can include receiving, by the computing device and from a pressure sensor, multiple pressure measurements indicating multiple pressures in the pressurization subsystem over a time period. The method can include generating, by the computing device and based on the multiple predetermined values and the multiple pressure measurements, a model representing a relationship between pressure in the pressurization subsystem and time. The method can include predicting, by the computing device and using the model, pressures in the pressurization subsystem over a future period of time that is subsequent to the time period.

[0060] Example #16: The method of Example #15 may feature determining, by analyzing the predicted pressures in the pressurization subsystem over the future period of time, that a rate of decay of the pressure in the pressurization subsystem is less than an acceptable decay rate for an acceptable period of time.

[0061] Example #17: The method of Example #16 may feature the acceptable decay rate being less than five psi or 34,473.785 Pa per minute, and the acceptable period of time being at least five minutes.

[0062] Example #18: The method of any of Examples #15-17 may feature causing, prior to the time period, a pump of the pressurization subsystem to pump an oil-based mud or a synthetic-based mud through the pressurization subsystem to pressurize the pressurization subsystem.

[0063] Example #19: The method of any of Examples #15-18 may feature determining, by analyzing the predicted pressures in the pressurization subsystem

over the future period of time, a pressure level at which the pressure in the pressurization subsystem is substantially stable. The method may also feature determining that the pressure level is within an acceptable range of pressures.

[0064] Example #20: The method of Example #19 may feature the acceptable range of pressures being between 1,000 psi or 6,894,757 Pa and 20,000 psi or 137,895,140 Pa. The method may feature the model being based on a thermal-cooling characteristic of the blowout preventer.

[0065] The foregoing description of certain examples, including illustrated examples, has been presented only for the purpose of illustration and description and is not intended to be exhaustive or to limit the disclosure to the precise forms disclosed. Numerous modifications, adaptations, and uses thereof will be apparent to those skilled in the art without departing from the scope of the disclosure.

CLAIMS

1. A system comprising:

a pressure sensor that is positionable in a pressurization subsystem for pressurizing a blowout preventer, the pressure sensor for detecting pressure in the pressurization subsystem; and

a computing device communicatively coupled to the pressure sensor and including a processing device and a memory device on which instructions are stored for causing the processing device to:

receive a plurality of predetermined values associated with pressure changes in the pressurization subsystem over time;

receive, from the pressure sensor, a plurality of pressure measurements indicating a plurality of pressures in the pressurization subsystem over a time period;

generate, based on the plurality of predetermined values and the plurality of pressure measurements, a model representing a relationship between pressure in the pressurization subsystem and time; and

predict, using the model, pressures in the pressurization subsystem over a future period of time that is subsequent to the time period.

2. The system according to claim 1;

wherein the model comprises the following equation:

$$P(t) = A_0 + A_1^{-m1t} + A_2^{-m2t}$$

where P(t) can be the pressure at time t; A_0, A_1 and A_2 can be values determined by the computing device; m_1 and m_2 can be constants or values determined by the computing device; wherein m_1 and m_2 can also be predetermined values from a previous blowout preventer test and can be characteristic of the blowout preventer or a well system.

3. The system of claim 1, wherein the memory device further includes instructions for causing the processing device to:

determine, by analyzing the predicted pressures in the pressurization subsystem over the future period of time, a rate of decay of the pressure in the pressurization subsystem during the future period of time; and

determine that the rate of decay is within a range of acceptable decay rates.

4. The system of claim 3, wherein the range of acceptable decay rates is between 20,684.27 Pascals (Pa) per minute and 34,473.79 Pa per minute.

5. The system of claim 4, wherein the memory device further includes instructions for causing the processing device to:

determine, by analyzing the predicted pressures in the pressurization subsystem over the future period of time, that the rate of decay will be within the range of acceptable decay rates for an acceptable period of time that is at least five minutes long.

6. The system of claim 1, wherein the memory device further includes instructions for causing the processing device to:

determine, by analyzing the predicted pressures in the pressurization subsystem over the future period of time, a pressure level at which the pressure in the pressurization subsystem is substantially stable; and

determine that the pressure level is within an acceptable range of pressures.

7. The system of claim 6, wherein the acceptable range of pressures is between 6,894,757 Pa and 137,895,146 Pa.

8. The system of claim 1, wherein the model is based on a thermal-cooling characteristic of the pressurization subsystem.

9. A non-transitory computer-readable medium in which instructions executable by a processing device are stored for causing the processing device to:

receive a plurality of predetermined values associated with pressure changes in a pressurization subsystem over time, the pressurization subsystem being for pressurizing a blowout preventer in a well system;

receive, from a pressure sensor, a plurality of pressure measurements indicating a plurality of pressures in the pressurization subsystem over a time period; generate, based on the plurality of predetermined values and the plurality of pressure measurements, a model representing a relationship between pressure in the pressurization subsystem and time; and

predict, using the model, pressures in the pressurization subsystem over a future period of time that is subsequent to the time period.

10. The non-transitory computer-readable medium according to claim 9, wherein the model comprises the following equation:

$$P(t) = A_0 + A_1^{-m1t} + A_2^{-m2t}$$

where P(t) can be the pressure at time t; A_0, A_1 and A_2 can be values determined by the computing device; m_1 and m_2 can be constants or values determined by the computing device; wherein m_1 and m_2 can also be predetermined values from a previous blowout preventer test and can be characteristic of the blowout preventer or a well system.

11. The non-transitory computer-readable medium of claim 9, further comprising instructions for causing the processing device to determine, by analyzing the predicted pressures in the pressurization subsystem over the future period of time, that a rate of decay of the pressure in the pressurization subsystem will remain within a range of acceptable decay rates for an acceptable period of time.

12. The non-transitory computer-readable medium of claim 11, wherein the range of acceptable decay rates is between 20,684.27 Pa per minute and 34,473.79 Pa per minute, and the acceptable period of time is at least five minutes.

13. The non-transitory computer-readable medium of claim 9, further comprising instructions for causing the processing device to, prior to the time period, cause a pump of the pressurization subsystem to communicate an oil-based mud or a synthetic-based mud through the pressurization subsystem to pressurize the pressurization subsystem.

14. The non-transitory computer-readable medium of claim 9, further comprising instructions for causing the processing device to:

determine, by analyzing the predicted pressures in the pressurization subsystem over the future period of time, a pressure level at which the pressure in the pressurization subsystem is substantially stable; and

determine that the pressure level is within an acceptable range of pressures.

15. The non-transitory computer-readable medium of claim 14, wherein the acceptable range of pressures is between 6,894,757 Pa and 137,895,146 Pa.

16. The non-transitory computer-readable medium of claim 9, wherein the model is based on a thermal-cooling characteristic of the blowout preventer.

17. A method comprising:

receiving, by a computing device, a plurality of predetermined values associated with pressure changes in a pressurization subsystem over time, the pressurization subsystem being for pressurizing a blowout preventer in a well system;

receiving, by the computing device and from a pressure sensor, a plurality of pressure measurements indicating a plurality of pressures in the pressurization subsystem over a time period;

generating, by the computing device and based on the plurality of predetermined values and the plurality of pressure measurements, a model representing a relationship between pressure in the pressurization subsystem and time; and

predicting, by the computing device and using the model, pressures in the pressurization subsystem over a future period of time that is subsequent to the time period.

18. The method according to claim 17, wherein the model comprises the following equation:

$$P(t) = A_0 + A_1^{-m1t} + A_2^{-m2t}$$

where P(t) can be the pressure at time t; A_0, A_1 and A_2 can be values determined by the computing device; m_1 and m_2 can be constants or values determined by the computing device; wherein m_1 and m_2 can also be predetermined values from a previous blowout preventer test and can be characteristic of the blowout preventer or a well system.

19. The method of claim 17, further comprising determining, by analyzing the predicted pressures in the pressurization subsystem over the future period of time, that a rate of decay of the pressure in the pressurization subsystem is less than an acceptable decay rate for an acceptable period of time.

20. The method of claim 19, wherein the acceptable decay rate is less than 34,473.79 Pa per minute, and the acceptable period of time is at least five minutes.

21. The method of claim 17, further comprising causing, prior to the time period, a pump of the pressurization subsystem to pump an oil-based mud or a synthetic-based mud through the pressurization subsystem to pressurize the pressurization subsystem.

22. The method of claim 17, further comprising:

determining, by analyzing the predicted pressures in the pressurization subsystem over the future period of time, a pressure level at which the pressure in the pressurization subsystem is substantially stable; and

determining that the pressure level is within an acceptable range of pressures.

23. The method of claim 22, wherein the acceptable range of pressures is between 6,894,757 Pa and 137,895,146 Pa, and wherein the model is based on a thermal-cooling characteristic of the blowout preventer.