WELLBORE SYSTEM AND METHOD USING A FLOW-ACTUATED DIVERTER VALVE

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention generally relates to a system and methodology for producing fluids from a well.

Description of Related Art

[0002] A wellbore is drilled into a formation containing a desirable production fluid, e.g. a hydrocarbon-based fluid, and the production fluid is pumped to a collection location. The production fluid often is pumped by a submersible pumping system, such as an electric submersible pumping system. An electric submersible pumping system typically comprises a submersible pump powered by a submersible motor. For example, the submersible pump may be a centrifugal pump having impellers rotated by the submersible motor to draw in fluid from the surrounding wellbore. This fluid is produced upwardly, often through a tubing string that can extend for substantial distances through the wellbore to, for example, a surface location.

[0003] When using downhole pumps to artificially lift the fluid from the wellbore, solids, e.g. sand, wax, and other solid materials, can be produced with the desired well fluid. If the submersible pump is turned off, a substantial column of fluid stands within the tubing string above the pumping system and often tends to fall back through the pumping system. The solids within the column of fluid segregate and move to the bottom of the tubing string where they can plug and damage the pumping system. GB 2411416 describes a diverter device in which the production flow flows through an interior of the device, which may thus cause undue friction loss and may add to pumping energy requirement.

BRIEF SUMMARY OF THE INVENTION

[0004] In general, the present invention provides a system and methodology that enables the removal of solids before they are able to plug or damage a downhole pumping system upon stoppage of the pumping system. A diverter valve is coupled to a

tubing through which well fluid is produced by a downhole pumping system. The diverter valve automatically actuates to a flow position when a well fluid is pumped by the downhole pumping system. However, when the flow of production fluid stops, the diverter valve automatically transitions to expose an exit port through which a backflow of fluid and solids can move from the tubing into the surrounding wellbore without passing into the pumping system. The automatic transition of the diverter valve to expose the exit port occurs when the production flow is interrupted regardless of whether the internal pressure within the tubing has equalized with the external pressure of the surrounding wellbore.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Certain embodiments of the invention will hereafter be described with reference to the accompanying drawings, wherein like reference numerals denote like elements, and:

[0006] Figure 1 is a front elevation view of a downhole pumping system deployed in a wellbore, according to an embodiment of the present invention;

[0007] Figure 2 is a schematic illustration of a diverter valve that can be used in the system of Figure 1, according to an embodiment of the present invention;

[0008] Figure 3 is a schematic illustration similar to Figure 2 but showing the diverter valve in a different position, according to an embodiment of the present invention;

[0009] Figure 4 is a schematic illustration of another embodiment of the diverter valve illustrated in Figure 2;

[0010] Figure 5 is a schematic illustration similar to Figure 4 but showing the diverter valve in a different position, according to an embodiment of the present invention;

[0011] Figure 6 is a schematic illustration of another embodiment of the diverter valve illustrated in Figure 2; and

[0012] Figure 7 is a schematic illustration similar to Figure 6 but showing the diverter valve in a different position, according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0013] In the following description, numerous details are set forth to provide an understanding of the present invention. However, it will be understood by those of ordinary skill in the art that the present invention may be practiced without these details and that numerous variations or modifications from the described embodiments may be possible.

[0014] The present invention generally relates to a system and methodology for pumping fluids from a wellbore and for protecting the pumping equipment. The system uses a downhole pumping system which pumps wellbore fluids through a diverter valve and a tubing to a desired collection location. If the flow of pumped fluid is stopped or sufficiently reduced, the diverter valve automatically actuates and diverts any backflow of fluids and solids from the tubing into the surrounding wellbore. This diversion of fluid to the wellbore avoids any blockage or damage to the pumping system due to solids within the fluid column.

[0015] The system and method can be utilized with a variety of downhole pumping systems. One embodiment comprises a downhole submersible pumping system, such as an electric submersible pumping system, as illustrated in Figure 1. As illustrated, a well system 20 comprises an electric submersible pumping system 22, a diverter valve 24 and a tubing 26. The diverter valve 24 is illustrated as coupled between electric submersible pumping system 22 and tubing 26. Furthermore, the diverter valve 24 comprises an exit port or dump port 28 through which fluid within tubing 26 can exit into

a surrounding wellbore 29 when the flow of pumped fluid drops, such as upon shutdown of pumping system 22.

[0016] In the embodiment illustrated, downhole electric submersible pumping system 22 is disposed in wellbore 29 which is drilled or otherwise formed in a geological formation 30. Electric submersible pumping system 22 is suspended below a wellhead 32 located, for example, at a surface 34 of the earth. Pumping system 22 is suspended by tubing 26, e.g. production tubing, coiled tubing, or other tubing through which a well fluid is produced by the pumping system 22.

[0017] As illustrated, wellbore 29 is lined with a wellbore casing 38 having perforations 40 through which fluid flows between formation 30 and wellbore 29. For example, a hydrocarbon-based fluid may flow from formation 30 through perforations 40 and into wellbore 29 adjacent electric submersible pumping system 22. Upon entering wellbore 29, pumping system 22 is able to produce the fluid upwardly through diverter valve 24 and tubing 26 to wellhead 32 and on to a desired collection point.

[0018] Although electric submersible pumping system 22 may comprise a wide variety of components, the example in Figure 1 is illustrated as having a submersible pump 42, a pump intake 44, and an electric motor 46 that powers submersible pump 42. Submersible pump 42 may comprise a single or multiple pumps coupled directly together or disposed at separate locations along the submersible pumping system 22.

[0019] Electric motor 46 receives electrical power via a power cable 48 and is protected from deleterious wellbore fluid by a motor protector 50. In addition, pumping system 22 may comprise a variety of other components depending on the type of pumping environments and applications for which it is designed. By way of example, the pumping system 22 may comprise a sensor unit 52 disposed at its lower end for sensing a variety of wellbore parameters.

[0020] The well system 20 uses selected porting to enable fluid within tubing 26 and any solids within the fluid to be dumped to wellbore 29 when, for example, electric submersible pumping system 22 is turned off. When pumping is again initiated, a movable mechanism is moved within diverter valve 24 to open a flow port and block the exit port 28 by utilizing a pressure loss resulting from a convoluted fluid flow through the diverter valve. This pressure loss enables activation of the mechanism through use of differential pressure acting on the mechanism as fluid is being pumped. Stopping the flow causes immediate equalizing of pressure and initates a return movement of the mechanism with minimal force. This enables the flow diversion to be controlled by fluid flow rather than by direct pressure.

[0021] Referring to Figure 2, an example of a diverter valve 24 is illustrated. In this embodiment, diverter valve 24 comprises a flow passage 54 through which well fluid is pumped by pump 42 during production of a desired well fluid, such as a hydrocarbon-based fluid. Flow passage 54 may be axially offset from tubing 26 to create a convoluted flow path. Diverter valve 24 also comprises a movable mechanism 56 which is movable between exit port 28 and a primary flow port 58 through which pumped well fluid enters flow passage 54. Movable mechanism 56 comprises a member 60 that may be moved between a position blocking primary flow port 58, as illustrated in Figure 2, and a position blocking exit port 28, as illustrated in Figure 3. In this embodiment, member 60 comprises a piston 62 slidably mounted in a cylinder 64 that may be oriented generally parallel with flow passage 54 to enable movement of member 60 between primary flow port 58 and exit port 28. Member 60 may be formed with piston 62 moving proximate primary flow port 58 and a second piston or other flow blocking member 65 moving proximate exit port 28 to selectively open and close the exit port.

[0022] When pump 42 stops and there is no flow of pumped fluid, the pressure acting on both ends of member 60 equalizes, and a biasing member 66, such as a spring, is able to move member 60 with minimal force to a position blocking primary flow port 58. In this position, exit port 28 is open, allowing the contents within tubing 26 to exit into wellbore 29 through exit port 28, as illustrated by arrows 68 of Figure 2.

[0023] Once pump 42 starts pumping well fluid, the pressure of the well fluid pushes piston 62 and moves member 60 along cylinder 64 to open primary flow port 58 and close exit port 28, as illustrated in Figure 3. The differential pressure of the pumped fluid is able to overcome the relatively small biasing force of biasing member 66. When pump 42 is pumping properly, the pressure P_1 acting on one end of member 60 is always greater than the pressure P_2 (see Figure 3), thus holding member 60 in a position enabling upward flow of pumped fluid through primary flow port 58, flow passage 54, and up through tubing 26, as illustrated by arrows 70. However, upon stoppage of pump 42, the flow pressure losses no longer occur and P_1 equals P_2. Under this condition, biasing member 66 pushes member 60 back to the position illustrated in Figure 2 in which primary flow port 58 is blocked and exit port 28 is open to enable backflow of fluid from tubing 26 into the surrounding wellbore 29.

[0024] Another embodiment of the movable mechanism 56 is illustrated in Figures 4 and 5. In this embodiment, movable mechanism 56 comprises a rotating ball valve 72 having a flow passage 74 therethrough. Ball valve 72 is connected to a piston 76 by a linkage 78 that may be pivotably coupled to the ball valve 72 and to the piston 76. Additionally, a biasing member 66, such as a spring, is positioned between piston 76 and a stop 80 to bias piston 76 toward a position blocking flow through primary flow port 58, as illustrated in Figure 4. In this position, fluid within tubing 26 is allowed to flow downwardly through flow passage 74 of ball valve 72 and into the surrounding wellbore 29, as illustrated by arrows 82. In this embodiment, a pressure equalization opening 84 is disposed through piston 76 to keep the pressures acting on both sides of piston 76 equal when pump 42 is not producing a flow of pumped fluid.

[0025] However, when a flow of well fluid is initiated by pump 42, an unequal pressure situation is again created, as described with reference to Figure 3. This pressure differential is sufficient to move piston 76 against the biasing force exerted by biasing member 66 and to open primary flow port 58, as illustrated in Figure 5. The movement of piston 76 also rotates ball valve 72, thereby moving flow passage 74 and effectively

closing exit port 28. In this position, well fluid is pumped upwardly through diverter valve 24 via flow passage 54 and continues upwardly through tubing 26, as illustrated by arrows 86.

[0026] Another embodiment of diverter valve 24 is illustrated in Figures 6 and 7. In this embodiment, diverter valve 24 is created by a first Y-tool 90 coupled to a second Y-tool 92 to form a dual Y-tool 94. First Y-tool 90 comprises a first leg 96 and a second leg 98, and second Y-tool 92 comprises a corresponding first leg 100 and a corresponding second leg 102 that are connected to first leg 96 and second leg 98, respectively. A crossover tube 104 connects first leg 96 to second leg 98 at the top of first Y-tool 90, and a crossover tube 106 connects first leg 100 to second leg 102 at the top of second Y-tool 92. The crossover tube 106 creates primary flow port 58, and the crossover tube 104 directs the backflow of fluid to exit port 28 formed in first leg 96, as illustrated in Figure 6.

[0027] In this embodiment, a piston 108 is positioned for sliding movement within first legs 96 and 100 for movement between mechanical stops 110 and 112. Stop 112 may be used to block movement of piston 108 past primary flow port 58, and stop 110 may be used for mounting a biasing member 66 against piston 108. Effectively, the location of mechanical stops 110 and 112 enables movement of piston 108 between a position blocking flow through primary flow port 58, as illustrated in Figure 6, and a position blocking flow through exit port 28, as illustrated in Figure 7. The biasing member 66, e.g. a spring, is used to bias piston 108 toward a position blocking primary flow port 58. Also, a plug or other blockage 114 is positioned in second leg 102 to prevent downflow therethrough. When the pump 42 is off, pressure on both ends of piston 108 is equalized, and biasing member 66 moves piston 108 into the position blocking primary flow port 58. Fluid and solids within tubing 26 flow downwardly through tubing 26, through crossover tube 104, and out through exit port 28 into the surrounding wellbore.

[0028] When pump 42 is operated, the pressure P_1 becomes greater than the pressure P_2 as described above and as further illustrated in Figure 7. This pressure differential forces piston 108 to move to a position that opens primary flow port 58 and blocks exit port 28. In this position, well fluid is pumped upwardly through diverter valve 24. The pumped fluid flows through flow passage 54, which extends through crossover tube 106 and second leg 98, before continuing upwardly through tubing 26, as illustrated by arrows 116. If pump 42 is stopped, the pressure P_2 once again equalizes with the pressure P_1, and piston 108 is moved by spring 66 to block primary flow port 58, thereby opening exit port 28 and enabling backflow of fluid and solids through exit port 28 into the surrounding wellbore 29. It should be noted the formation of the dual Y-tool design can be accomplished by stacking and connecting standard Y-tools, or the general configuration can be custom-formed with appropriately sized tubing for a given application.

[0029] The components of the well system 20 and the specific structure of the diverter valve 24 can vary according to the type of wellbore application, well environment, and desired design parameters. For example, the diverter valves can have various component designs that are able to utilize pressure loss incurred through convoluted fluid flow, thereby providing control over the opening and closing of primary flow ports and exit ports. Additionally, various pistons or other movable mechanisms can be constructed for movement under the influence of differential pressures and pressure equalization, as generally described above.

[0030] Accordingly, although only a few embodiments of the present invention have been described in detail above, those of ordinary skill in the art will readily appreciate that many modifications are possible without materially departing from the teachings of this invention. Accordingly, such modifications are intended to be included within the scope of this invention as defined in the claims.

CLAIMS

What is claimed is:

1. A system to control fluid flow in a wellbore, comprising:

a wellbore fluid diverter valve that may be coupled to a tubing string, the wellbore fluid diverter valve comprising:

a primary flow port through which a pumped fluid flows;

an exit port that opens a flow route between an interior of the wellbore fluid diverter valve and the wellbore; and

a movable mechanism movable by the pumped fluid to open the primary flow port and to close the exit port, the movable mechanism being biased to close the primary flow port and to open the exit port upon stoppage of the pumped fluid, wherein the movable mechanism comprises a piston and a cylinder for slidably receiving the piston; and

a generally parallel flow passage, axially offset from the movable mechanism, through which the pumped fluid flows.

2. The system as recited in claim 1, further comprising a tubing and a submersible pumping system to move the pumped fluid through the wellbore fluid diverter valve and the tubing.

3. The system as recited in claim 1, wherein the movable mechanism comprises a spring to bias the piston toward a position in which the primary flow port is closed.

4. The system as recited in claim 1, wherein the movable mechanism comprises a ball valve positioned in the exit port and coupled to the piston.

5. The system as recited in claim 4, wherein the piston comprises a pressure equalizing opening therethrough.

6. The system as recited in claim 1, wherein the wellbore fluid diverter valve comprises a housing having the form of a dual Y-tool.

7. A downhole pumping system, comprising:

a submersible pumping system that may be deployed in a wellbore to pump a wellbore fluid, the submersible pumping system comprising a submersible pump powered by a submersible electric motor;

a tubing coupled to the submersible pumping system to direct the wellbore fluid; and

a diverter valve coupled to the tubing, the diverter valve being biased to a dump position routing back flow of wellbore fluid into the wellbore, the diverter valve responding to a differential pressure created by operation of the submersible pump to open a flow port for forward flow of wellbore fluid pumped through the tubing, the diverter valve being located in an axially offset position relative to an adjacent flow passage through which fluid is produced by the submersible pumping system.

8. The system as recited in claim 7, wherein the diverter valve comprises a piston mechanism slidably positioned to block either an exit port, through which the back flow of wellbore fluid is routed into the wellbore, or the flow port, to prevent back flow therethrough when the flow of pumped wellbore fluid stops.

9. The system as recited in claim 8, wherein the diverter valve comprises a spring positioned to bias the piston mechanism to a position blocking flow through the flow port.

10. The system as recited in claim 7, wherein the diverter valve comprises a piston coupled to a ball valve, the piston being biased to open the ball valve and enable the back flow of fluid from the tubing into the wellbore when the submersible pumping system stops pumping.

11. The system as recited in claim 7, wherein the diverter valve comprises a movable mechanism movable by pumped wellbore fluid to open a flow port and close an exit port, the movable mechanism being biased to close the flow port and to open the exit port upon stoppage of the pumped wellbore fluid.

12. The system as recited in claim 7, wherein the diverter valve comprises a housing having the form of a dual Y-tool.

13. A method, comprising:

coupling a diverter valve between a submersible pumping system disposed in a wellbore and a tubing through which a well fluid is produced;

providing the diverter valve with a member movable between a production flow position and an exit flow position in which well fluid within the tubing is dumped into the wellbore, the member comprising a piston slidably received in a cylinder;

moving the member to the production flow position via a differential pressure of well fluid pumped by the submersible pumping system;

pumping well fluid through a generally parallel flow passage; and

biasing the member with sufficient force to move the member to the exit position when the flow of pumped well fluid stops.

14. The method as recited in claim 13, wherein providing comprises providing the piston in a form that is movable between a primary flow port and an exit port.

15. The method as recited in claim 13, wherein moving comprises moving the member to expose a primary flow port through which the well fluid is pumped through the diverter valve.

16. The method as recited in claim 13, wherein biasing comprises biasing the member with a spring.

17. The method as recited in claim 13, further comprising rotating a ball valve to enable fluid flow from the tubing to the wellbore when the diverter valve is in the exit position.

18. The method as recited in claim 13, wherein providing comprises providing a slidable piston within a dual Y-tool.

19. A system, comprising:

a tubing deployed in a wellbore to carry a well fluid;

a diverter valve coupled to the tubing, the diverter valve comprising:

a convoluted flow passage through which the well fluid is delivered to the tubing;

a cylinder and a piston mechanism slidably mounted in the cylinder;

a primary flow port through which the well fluid flows into the convoluted flow passage when produced; and

an exit port exposing an interior of the tubing to the wellbore;

the piston mechanism being moved to open the primary flow port by a flow of well fluid produced through the convoluted flow passage, the piston mechanism moving to block the primary flow port and open the exit port when the flow of well fluid decreases sufficiently, the piston mechanism being axially offset from the convoluted flow passage.

20. The system as recited in claim 19, wherein the piston mechanism comprises a spring positioned against a piston to bias the piston mechanism toward opening the exit port.

21. The system as recited in claim 19, wherein the piston mechanism comprises a ball valve moved by a piston to control flow through the exit port.

22. The system as recited in claim 19, wherein in the piston mechanism is positioned in a housing having the form of a dual Y-tool.